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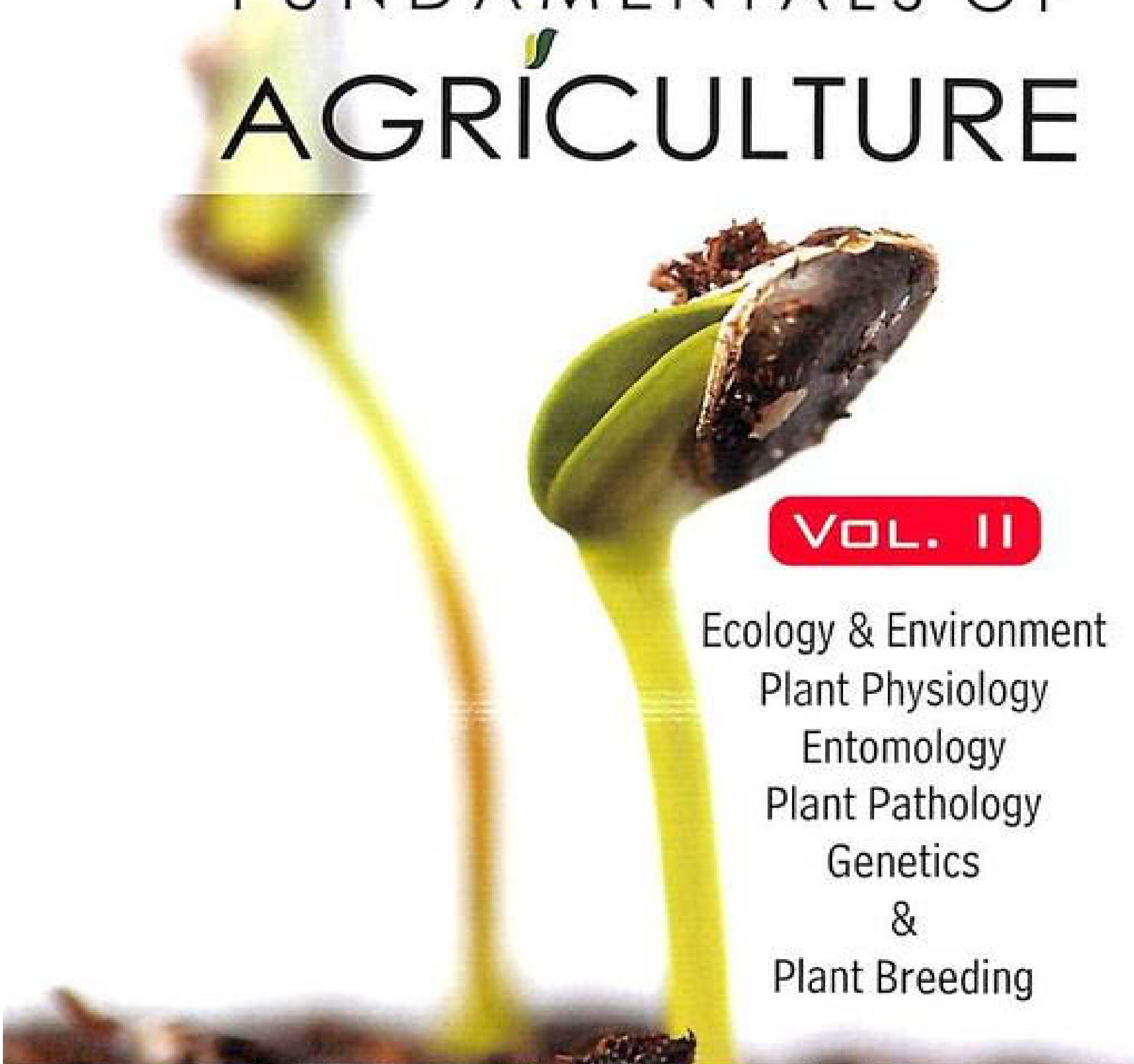

VOL. II

Ecology & Environment
Plant Physiology
Entomology
Plant Pathology
Genetics
&
Plant Breeding




Arun Katyayan

Useful for undergraduate and post-graduate students
and
Central/State Civil Services, Forest services, Banking Services,

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Fundamentals of Agriculture

Ecology & Environment
Plant Physiology
Entomology
Plant Pathology
Genetics &
Plant Breeding

Vol - 2

By
Arun Katyayan

(Fully Revised & Enlarged Edition)

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CONTENTS

1. Ecosystem : **1 - 8**
Meaning, Abiotic & biotic components, Autotrophic Heterotrophic components, Types of Ecosystem, Energy Flow in Ecosystem, Ecological Pyramid; Pyramid of energy, number & biomass.

2. Bio-diversity and its Conservation : **9 - 33**
Meaning, Genetic, species & community diversity, Importance of biodiversity, Threat to biodiversity, Extinction of species, Red data book, Biodiversity in India, Endangered species in India, Indian Vultures, Hot spots, conservation of biodiversity, wildlife sanctuary, National Park, Biosphere reserve and their differences, Important National Parks & Sancturies, Biosphere reserves in India, Ramsar site, Sacred Groves, Silent valley, Germplasm bank, Environmental laws, Indian forest Act.

3. Environmental Pollution : **34 - 79**
Pollution and its type, **Air pollution** : Air pollutants, photochemical, Acid rain, ozone hole, particulate matters, aerosols, prevention and control of air pollution, **Noise Pollution:** decibel & Hertz, effects of noise pollution, source of noise, noise intensity and different source, control of noise pollution; **water pollution:** sewage other wastes, industrial effeluents, Agl. discharges, thermal pollution, water pollutions, **Marine pollution**, Mercury Pollution, control of water pollution; soil pollution. Sources, effects, control of soil pollution; **Nuclear pollution:** Sources, effects & control of nuclear pollution; Bioremediation, phytoremediation, categories of phyto remediation, some technical definitions relevant to bioremediation.

4. Disaster and Disaster management : **80 - 91**
Natural Disaster: Earthquake, Landslide, Floods, Cyclones and their management; Tsunami, Manmade Disaster.

5. Water Relation : **92 - 111**
Introduction, Diffusion, Osmosis, Osmotic Potential, Water Potential, Turgor Pressure, Chemical Potential, Osmotic Relations, Endoosmosis, Exo-osmosis, Role of Osmosis, Factors

affecting osmotic pressure, Imbibition, Plasmolysis, Absorption of water, Active absorption and their theories, Passive absorption, Factors affecting the rate of water absorption, Ascent of sap and different theories, Loss of water, Transpiration, Difference between transpiration and evaporation, Stomata and their types, Mechanism of stomatal opening and closing, Guttation, Bleeding, Difference between transpiration & guttation.

6. Photosynthesis : **112 - 143**
Introduction, Photosynthetic Pigments, Photosynthesis, Light reactions, Robert Emerson's work and red drop, Dark reactions, Calvin Cycle, Hatch and Slack Cycle, CAM; Photorespiration, Factors affecting Photosynthesis.

7. Respiration : **144 - 164**
Introduction,Typesofrespiration,Mechanism of respiration, Glycolysis, Anaerobic respiration, Aerobic respiration, Link, Krebs cycle, Difference between Calvin cycle and Kerbs Cycle, Phosphorylation, Electron transport system, Energy released during respiration, Efficiency of respiration, Respiratory Quotient, Difference between aerobic and anaerobic respiration, Difference between respiration and photorespiration, Factors affecting respiration, Pasteur effect, Climacteric rise.

8. Enzymes : **165 - 169**
Meaning, Types of enzymes, Mode of Action, Classification, Nature and properties, Factors affecting Enzyme reaction.

9. Growth, Harmones and Growth Regulators : **170 - 181**
Growth and Development, Phases of Growth, Factors affecting growth and development, Growth Harmones and regulators : Auxins, Gibberellins, Cytokinin, Abscisic acid (ABA), Ethylene, Difference between growth inhibitor and growth retardant.

10. Photoperiodism and Vernalisation : **182- 185**
Photoperiodism : Short day plants, Long day plants, Day neutral plants, Critical Period, Photoperiodic induction, Flowering stimulus, Vernalization and devernalisation.

11. Agricultural Entomology : An Introduction **186 - 190**
Insect-Pest, Entomology, Phyllum : Arthropoda, Insects :, Ticks/ Mites, Metamorphosis , Mouth Parts and its types , Damaging Stages, Bhopal Gas Tragedy :

12. Insecticides : 191 - 223

Mode of Action of Insecticides, Insecticides and their trade names, Inorganic Compounds, Organic Compounds, Synthetic Organic Compounds, DDT Analogs , BHC/HCH, Organo-phosphorus compounds, 'S' – Containing Insecticides, Carbamate Insecticides, Synthetic Pyrethroids, Acaricides, Fumigants, Rodenticides, Generations of Insecticides, Insecticide Additives, Types of Formulation, Liquid Formulation/Spray, Gaseous Formulation, Calculations Regarding Formulation

13. Plant Protection Equipments : 224 - 235

Dusters, Introduction, Hand-operated duster or Hand Duster, Power (operated) dusters, Sprayer, Introduction, Types of Pump, Function of nozzle, Types of nozzle, Hand Operated Sprayers, Hydraulic (Energy) Sprayers, Compression/Pneumatic/Air Sprayers, Gaseous Energy/Air Blast Sprayer, Power Sprayers, Pneumatic/ compression/Air Energy Sprayer, Gaseous Energy Sprayer, Centrifugal Energy Sprayer, Other Equipments.

14. Integrated Pest Management : 236 - 262

Introduction, Harmful Effects of Pesticides, Integrated Pest Management, Cultural Measures, Mechanical and Physical Measures, Biological control Measure, Successful examples of Bilogical agents used in Pest Management, Chemical Control, Pest Surveillance, Forecasting of pest attack, Introduction of pests from one country to other,Domestic Quarantine for Pests, Varietal Control, Male sterlie Technique, Use of IGR, Pheromones, Attractants & Repellants.

15. Stored Grain Pests : 263 - 268

Rice Weevil, Khapra beetle, Pulse beetle, Rice Moth, Lesser grain borer, Rust Red Flour bettle, Angoumois grain moth, Protection of Stored grain, Preventive Measures, Hygenic Measures, Physical Measures, Chemical Measures, Curative Measures, Aluminimum Phosphide. (Celephos)

16. Insect Pests of Some Crops : 269 - 287

Insect pest of Paddy Crop, Rice gall Midge/Fly, Yellow stem borer, Plant Hopper, Insectpest Management of Rice, Insect pests

of Cotton, American bollworm, Spotted bollworm, IPM in Cotton, Measures for Bollworms protection, Insect pests of Sugarcane, Sugarcane Leafhopper, Sugarcane root borer, Sugarcane shoot borer, Sugarcane top borer, Gurdaspur borer, IPM in sugarcane, Insect-Pest of Pulses, Pod borer, Gram cutworm, IPM in Pulses, Insectpests of oilseeds , White grub, Mustard Aphid, Mustard sawfly, Painted bug, IPM in Oilseed, Insect Pests of Vegetables, Fruit fly, Red pumpkin beetle, Brinjal borer, Hadda beetle, Jassids (Leaf hoppers), Tomato fruits borer, Diamond-black moth, Mustard Aphid, Painted bug, Insect Pests of fruits and Fruit trees, Mango hopper, Fruit fly, Mealybug, Fruit sucking moth, Citrus Psylla, Lemon butterfly, Anarbutterfly, San Jose Scale, Woolly aphid , Apple root borer.

17. Plant Pathology : An Introduction : **288 - 299**

An Introduction : Technical terms : An Introduction, Rust in India, Physioligical Specialization

18. Chemicals used in Disease Control : **300 - 309**

Fungicides, Types of Fungicides, Thiocarbamate Fungicides, Metallic dithiocarbamates, Other Organic Fungicides, Antibiotics, Systemic Fungicides, Organo–mercurial Fungicides, Fungicides and their name.

19. Plant Disease Control : **310 - 319**

Classification of Plant Disease Control Methods, General Principles of Plant Disease control, Avoidance of the pathogen, Exclusion of Inoculum, Types of seed treament, Eradication of the Pathogen, Protective Measures, Development of Resistance in Hosts, Therapy of Diseased Plants, BACTERIAL DISEASES, MYCOPLASMAL DISEASES, VIRAL DISEASES, Diseases caused by Nematodes.

20. Disease-details Table : **320 - 337**

21. Genetics : An Introduction : **338 - 344**

Heredity, Variation, Phenocopy, Gene, Plasmid, Genome, Allele/Allelomorph, Chromosome, History, : spontaneous generations, Preformation, Theory of epigenesis, Theory of

Inheritance of Acquired characters, Theory of Pangenesis, Germplasm theory, physical basis of heredity.

22. The Cell : **345 - 366**

History, Cell parts, Prokaryotic and eukaryotic cells, plasmalemma, Cell wall, Protoplasm, Nucleus, Nucleolus, Chromosome, Mitochondria, Plastids, Endoplasmic Reticulum, Ribosomes, Golgibody, Lysosome, Tonoplast, Plasmadesmata, Centrosome, Genetic material, DNA & RNA, Genetic Code.

23. Cell Division : **367- 379**

Cell division cycle, Amitosis, Endomitosis, Brachymeiosis, Mitosis, Meiosis.

24. Mendel's Laws : **380 - 389**

Mendel's life, Mendel's Work, Reason for Mendel's success, Mendel's observations, Mendel's Laws, Law of Segregation, Law of Independent Assortment, Deviations from Mendel's law, Back cross & Test Cross,

25. Dominance & Gene Interaction : **390 - 392**

Dominance, Penetrance, Expressivity, Pleiotropism, Lethality, Gene Interaction : Complementary genes, Epistasis, Inhibitory gene action, Duplicate genes, Polymeric gene action.

26. Linkage & Crossing Over : **393 - 394**

Introduction, Strength of linkage, Linkage maps or genetic map.

27. Sex linked, Sex influenced & Sex limited traits : **395 - 398**

Introducion, Sex linked traits, Non-disjunction of sex chromosomes, Sex-influenced traits, Sex limited traits.

28. Cytoplasmic or Extranuclear Inheritance : **399 - 400**

Introduction, Features of Cytoplasmic Inheritance, Practical application of cytoplasmic inheritance.

29. Modes of Reproduction & Pollination Control : **401 - 416**

Apomixis and its types, Modes of reproducion parthenogenesis, Vybrid, Flower, Anthesis, Mechanisms promoting self-pollination, Classification of crop species on the basis of their natural mode of pollination, Mechanism promoting cross-pollination, Self-Incompatibility, Male Sterility, Chemical hybridising Agent.

30. Qualitative & Quantitative Characters : **417 - 422**
Introduction, Qualitative Characters, Quantitative Characters, Pleiotropy, Penetrance & Expressivity, Gene Interaction. Polygenic inheritance, Phenotypic variance, Heritability.

31. Selection in Self-pollinated Crops : **423 - 428**
Progeny test, Pureline theory, Pureline Selection, Mass-Selection, pedigree method, Bulk method, Backcross method.

32. Selection in Cross-pollinated Crops : **429 - 446**
Hardy-Weinberg law, Inbreeding, Inbreeding Depression & Heterosis, Hybrid Vigour, its genetic basis, Hybridization, Metaxenia, Objectives of hybridization, types and procedure of hybridization, Emasculation and its techniques, Breeding method used in cross pollinated : population improvement, Mass selection progeny selection, Recurrent selection, GCA, SCA, Hybrid & Synthetic Varieties, Synthetic/Composite Varieties, Germplasm Complexes, Multiline Varieties.

33. Breeding for Disease & Insect Resistance : **447 - 448**
Pathogenicity, Development of diseases, Sources of disease or insect resistance, Methods of breeding.

34. Mutations in crop Improvement : **449-456**
Meaning, types of mutation & its Characteristics, Mutagens, Mutation breeding, γ -garden.

35. Polypoidy : **457-467**
Meaning, heteroploidy, Euploidy, Aneuploidy, Features of autopolypoids, Allopolypoids, Homoeologous chromosome, Amphidiploid, Synthesis of Triticale & Raphanobrassica, Evolution of Bread wheat, Amphidiploid Brassica sp., and Nicotiana tabacum.

36. Objective model Questions (With Answer) : **468 - 539**

Ecosystem

Meaning

Ecosystem = Eco + System
Eco ↓ Ecology
System ↓ Interaction unit

Here the term 'Ecology' was proposed by a German biologist Earnst Haeckel in his book 'Generalle Morphologie der Organismen' in the year 1866 but the word was coined by Hanns Reiter in 1885 from two Greek Words viz.-

Ecology = Oikos + logos
Oikos ↓ house/dwelling place
logos ↓ study

It means the Ecology is the study of living beings in their natural habitats. The surroundings of the living organisms are collectively called **Environment**.

The living organisms and its environment forms a functional basic unit which was named as Ecosystem by the British man Arthur **G. Tansley** in 1935. He defined the Ecosystem as follows:-

..... "The whole system (in the sense of physics) including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment of the biome-the habitat factors in the widest sense. Though the organisms may claim our primary interest, when we are trying to think fundamentally we can not separate them from their special environment, with which they form one physical system. It is the systems so formed which, form the point of view of the ecologist, are the basic units of nature on the face of the earth."

Hence the ecosystem is the ecological system or unit where all living and non-living factors of the environment interacts with each other and with their own components. Living factors are called **Biotic** components and non-living factors are called **Abiotic** components. These biotic and abiotic components of an ecosystem form the basic structure of the ecosystem. But the function of the

ecosystem is related to the flow of energy and cycling of materials through its structural components. The ecosystem may be of temporary nature viz. pond, crop land or of permanent nature viz. an ocean. The ecosystems are simply separated from each other with time and space, but functionally they are linked together and there are no functional boundaries between them.

Abiotic components

According to E.P.Odum (1971), abiotic components of an ecosystem are grouped into three main categories:-

a) Inorganic nutrients e.g. water, elements (K, Mg, Ca, N, P, etc.) and gases (O_2, CO_2, N_2, NH_3 etc.).

b) Organic compounds e.g. Protein, carbohydrate, lipid, fat etc.

c) Climatic factors e.g. Light, temperature, wind, rainfall, humidity etc.

The climatic condition and physical factors vary widely from place to place and thus greatly affects the distribution of organisms. The amount of abiotic components present in an ecosystem is called the **standing stage** or **standing quantity.**

Biotic Components

Living organisms like plants, animals and microorganisms present in the environmental system are called biotic components. On the basis of nutritional character, it is of two categories viz. (i) Autotrophic and (ii) Heterotrophic

Biotic components

- Autotrophic (Autotrophs)
  (producer of their own food)
  - Phototrophs
    (make their food through photosynthesis) e.g. green plant.
  - Chemotrophs
    (Make their food through chemosynthesis)
    e.g. chemosynthetic bacteria
- Heterotrophic (heterotrophs)
  (depend on primary producer)
  - Holozonic
    (consume the food through their mouth) e.g. Herbivores, (rabbit, deer) Carnivores (dogs, birds, insects) omnines (Man Bear)
  - Saprophytes
    (Take food from dead or decaying tissues in solution form) e.g. bacteria & fungi
  - Parasites
    (consume food from living protoplasms of another organism) e.g. Agaricus, other fungi & bacteria.

[A] Autotrophic components (Autotroph)

Autotroph = Auto + troph

Auto ↓ Self

troph ↓ nourishing

Such living organisms who produce their food themselves are called autotrophs. Therefore Autotrophs are the producers of the food and are called ***Primary producers*** of the ecosystem. Autotrophs are either phototrophs or chemotrophs.Phototrophs are such autotrophs who produce or make their food through photosynthesis whereas chemotrophs produce their food through chemosynthesis where energy is derived from oxidation-reduction (redox) reaction.

[B] Heterotrophic components / Heterotrophs

Such living organisms depend on autotrophs for their food and consume the matters built up by the primary producers. On the basis of consuming the food, heterotrophs are grouped into three categories:-

i) **Holozonic** : Such organisms consume their food through mouth e.g. Herbivores (herbs eater), Carnivores (flesh eater), Omnivores (both herbs and flesh eater). Herbivores are called the **primary consumers** because they feed on producers directly. Carnivores and Omnivores are the **secondary consumers**. The top carnivores (like vulture, hawk, lion, tiger etc) who feed on both primary and secondary consumers are called **Tertiary consumers**.

ii) **Saprophytes :** Sapros+phytes; Sapros means to absorb. Such organisms take their food (i.e. organic matter) in the solution form from dead or decaying tissues of plants and animals e.g. saprophytic bacteria.

iii) **Parasite:** Para+sitos; Para means beside and sitos means nutrition. Such organisms live on living protoplasm of another organism e.g. Fungi like Agaricus.

The saprophytes and the parasites are the microconsumers and are popularily known as decomposers/Reducers/Transformers/ saprotrophs or osmotrophs. The decomposers decompose the dead bodies of producer and consumers by feeding upon them. The transformers transform the complex compounds into basic inorganic forms. Thus due to decomposers and transformers the basic chemical substances are become available again and again

to be utilised by the producers. In this way these organisms play an important role in maintaining the dynamic nature of the ecosystem.

Types of ecosystem(E.S.):

- Earth Ecosystem
  - Natural Ecosystem
    - Terrestrial E.S.
      - Forest
        - Tropical rain forest
        - Tropical Deciduous
        - Temperate Deciduous
        - Conifers or Alpine or Taiga
      - Grass land
        - Pampas (in Argentina)
        - Prairies & Plains (North America)
        - Steppes (Eurasia)
        - Savana (Tropics)
        - Tussock (Newzealand)
      - Desert
        - Sahara (North Africa)
        - Kalahari (South Africa)
        - Thar (Rajasthan)
        - Atacama (Sourth America)
        - Gobi (Mongolia)
      - Tundra
      - Polar
    - Aquatic E.S.
      - Marine
        - Oceanic e.g. Ocean
        - Estuarine (Zone between sea & continent)
        - Deltaic e.g. Sunderban
      - Fresh water
        - Lentic (Standing fresh water) e.g. Lake, Pond etc.
        - Lotic (Running fresh water) e.g. River, spring
  - Artificial Ecosystem e.g. Pond, cropland, garden, well etc. plantations. i.e. man-made ecosystem

Energy flow in ecosystem

In our solar system, the sun is the ultimate source of energy. The producers (i.e. green plants) make their foods through photosynthesis by utilising solar radiations. The foods produced by the producers are consumed by the different levels of

consumers. The decomposers take their energy by decomposing the dead cells. Thus the energy is passed from one organism to the other organisms in the form of food. This energy transformation in ecosystem is technically called **bioenergetics** or energy cycle.

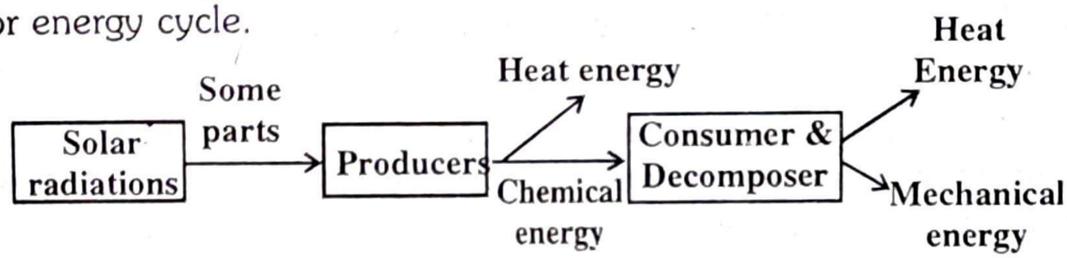

Fig. Unidirectional energy flow

The flow (conversion) of energy from one level to the another level causes 90% loss of energy in the form of respiration and heat and the flow of only 10% energy is occured. This flow of energy is unidirectional. The energy trapped by the autotrophs moves progressively through the various trophic level but never revert back to its previous level. In this way the energy level for consumer at the each level is not the same.

According to Lindemann(1942), only 10% of the energy entering in a particular trophic level of organism is available for transfer to the next trophic level. This law is known as **Lindmann's 10% law**. All the energy transfers in a food chain follow the 10% law which means that the energy available at each successive trophic level is 10% of the previous level. This is explained in the following figure:-

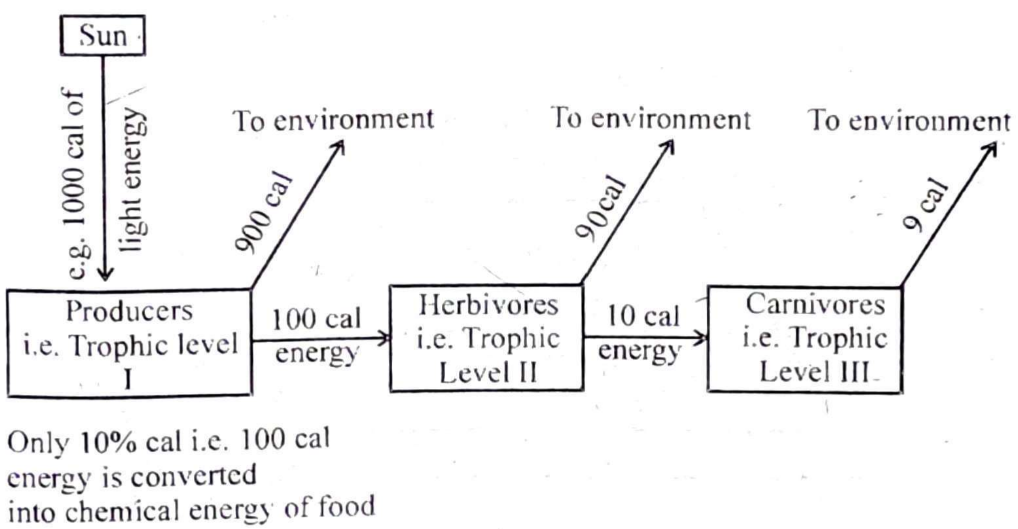

Fig. Lindeman's 10% Law

Ecological Pyramid

Various trophic levels of the ecosystem may be indicated graphically which is known as 'ecological pyramid'. The concept of ecological pyramid was first developed by a British ecologist Charles Elton (1927) to show various trophic levels in an ecosystem.

An ecological pyramid may be defined as a graphical representation of an ecological parameter like number, biomass or accumulated energy at different trophic levels in a food chain in an ecosystem.

There are three types of ecological pyramids -

a) Pyramid of Energy' based on the energy flow in different trophic levels

b) Pyramid of Number' based on the no. of organisms

c) Pyramid of Biomass' based on the biomass of organisms.

a) Pyramid of energy

It is drawn after taking into consideration the total quantity of energy utilised by the trophic levels in an unit area on a particular time. It is evident from the energy flow that there is always a gradual decrease in the energy content at every successive trophic level from producer to top consumers. Thus the energy pyramid is always upright.

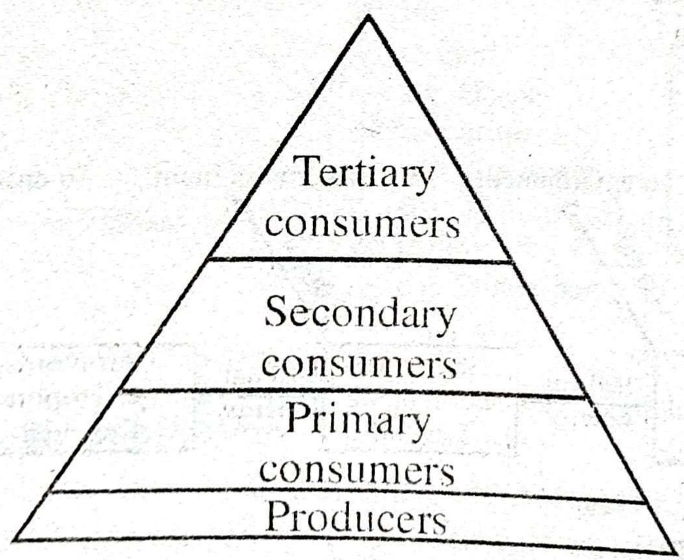

Fig. Upright pyramid of energy

b) Pyramid of number

It shows the number of individual organisms per unit area at each trophic level. The shape of pyramid varies from ecosystem to ecosystem. For example, in grassland ecosystem, the producers are mainly grasses and hence the maximum in number. This number shows a decrease towards primary consumers (herbivores), secondary and tertiary consumers (like hawk, lion) i.e. apex. Thus upright pyramid of number in grassland ecosystem is found. It is the same in aquatic ecosystem where producers are large in numbers per unit area due to their very small size. But in forest ecosystem, the producers are mainly large sized trees and their number is not so large but primary consumers like fruit eating birds, deers, elephants etc. constitute more in number than of producer. After primary consumers, there is a decrease in no. at each third and fourth trophic level. In a parasitic food chain, the pyramid of number is always inverted type because a single large tree support the large no. of fruit eating birds and each herbivore support the large no. of parasites.

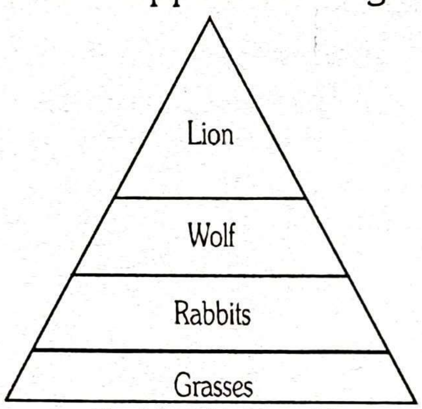

Fig. Upright pyramid of No. in Grassland Ecosystem

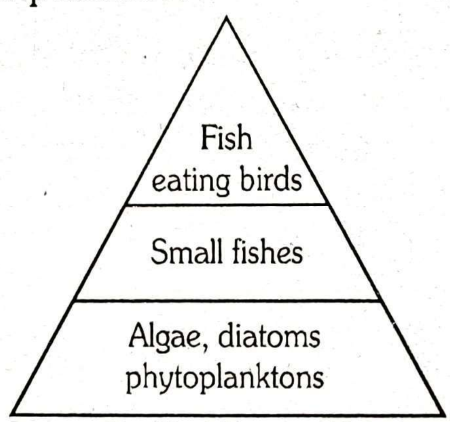

Fig. Upright pyramid of No. in Aquatic Ecosystem

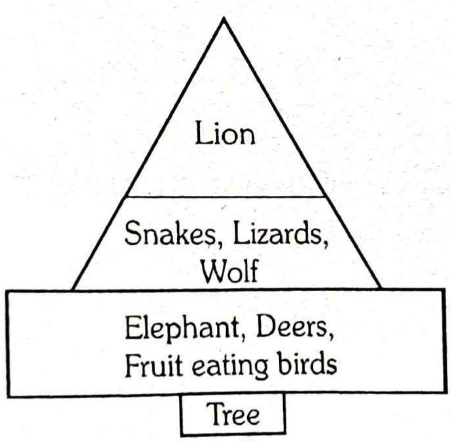

Fig. In Forest Ecosystem

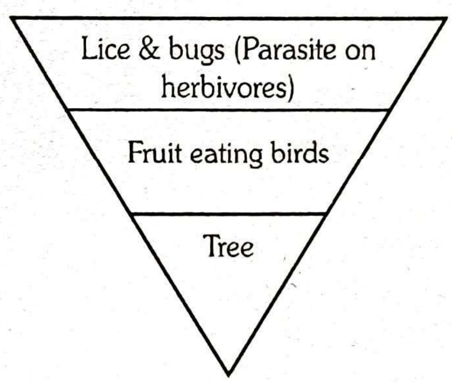

Fig. Inverted type in parastic food chain (Pyramid of number)

c) Pyramid of Biomass

It is of two types viz : upright and inverted in shape.

i) **Upright pyramid of biomass :** where larger weight of producers support a smaller weight of consumers. e.g. grassland & forest ecosystem.

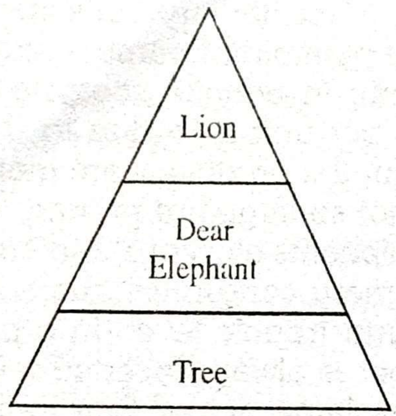

Fig. Upright pyramid of biomass in grassland & forest ecosystem

ii) **Inverted type pyramid of biomass :-** where smaller weight of producers supports a larger weight of consumers e.g. aquatic ecosystem.

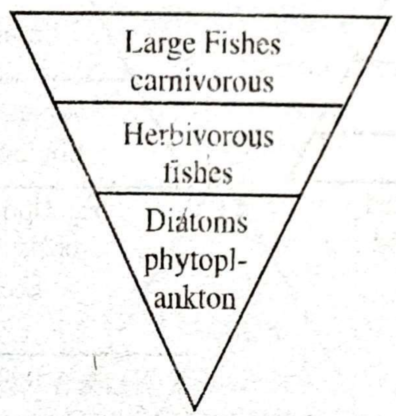

Fig. Inverted type of pyramid of biomass in aquatic ecosystem.

*

2 Bio-diversity and its Conservation

Meaning

Biodiversity is the short form of biological diversity. It is the variability among the living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and ecological complexes in which they are the part, and this includes diversity within species, between species and of the ecosystems. Biodiversity refers to the variety and variability among living organisms and the ecological complexes in which they occur. It is the sum total of the diversity in the biosphere in terms of number, variety and variability of all living organisms. The term biodiversity was coined by Walter G. Rosen in 1985. A concise definition of biodiversity is " the totality of genes, species, and ecosystems in a region" (IUCN, UNEP, 1992). Agrobiodiversity is the subset of biological diversity which is related to the agriculture. Thus agrobiodiversity is the diversity of the agricultural systems.

There are three hierachical levels of biodiversity :-

1) Genetic diversity

The diversity in the genetic make-up of a species is known as genetic biodiversity. The minute differences found within a species i.e., between the varieties, races or strains are due to slight variations in the genetic organisation. These minute differences may be in shape, size, quality of the product, resistance to insect, pest and diseases etc.

A species with a large no. of races, strains or varieties is considered to be rich and diverse in genetic organisation. If a species has more genetic diversity, it would be better in the changed environment. Lower diversity in a species leads to uniformity (i.e. monoculture).

2) Species diversity : A species is a group of organisms genetically so similar to each other that they can inter breed and produce fertile off-springs. A species is usually the unit of classification in most of the taxonomic works. Species are distinct units of diversity which play a specific role in an ecosystem. Species diversity refers to the variety of species within a region. The loss of one species has the consequences for the ecosystem.

3) Community and Ecosystem diversity

A community is a group of populations of different species in a given area. It includes all the populations of plants, animals and microorganisms in that particular area. Depending largely upon the availability of abiotic resources and conditions of the environment on ecosystem develops its own characteristic community of living organism. Different types of forests, grassland, lakes, ponds, rivers etc. represent diverse ecosystems each with a characteristic biotic community.

India is one of the 17 mega diverse countries which together possess 60-70% of the world's biodiversities. India ratified the international convention on Biodiversity (CBD) in 1994, and became a part of it. The CBD is an international legal instrument for promoting conservation and sustainable use of biological diversity taking into account the need to share cost and benefit between developed and developing countries and the ways and means to support innovation by local people. The 8th meeting of conference of the parties (COP) to the CBD was held in Curitiba, Brazil from 20-31 March, 2006.

A National Biodiversity Authority has been set up at Chennai vide Gazette notification dated 01.10.2003 under the Biological Diversity Act, 2002. The 17 mega diverse countries are (1) Bolivia 2) Brazil 3) China 4) Colombia 5) Costa Rica 6) Democratic Republic of Congo 7) Ecuador 8) India 9) Indonesia 10) Kenya 11) Madagascar 12) Malaysia 13) Mexico 14) Peru 15) Philippines 16) South Africa 17) Venezuela.

These countries are rich in biological diversity and associated traditional knowledge have been formed the group of Like Minded Megadiverse countries (LMMC). India was the president of LMMC for a period of two years from March 2004 to March 2006.

The Cartagena Protocol on biodiversity, the first international regulatory framework for safe transfer, handling and use of living modified organism (LMOs) was negotiated under the aegies of the convention on Biological Diversity.

India occupies nearly 2.5% of the global land mass but it has about 7.5% of the identified biological species.

Importance of Biodiversity

Diversity is the beauty of nature. Biodiversity is the source of food, medicines, pharmaceutical drugs, fibres, rubber, timber and many more. There are three major importance of biodiversity for the human race:-

[A] Biodiversity serves as a valuable natural resources of our agriculture, livestock, forestry and fisheries. About 90% of all Indian medicines are obtained from plants. Biodiversity in the wild form is useful to agriculture in two ways viz.:-

(i) as a source of new crop

(ii) as a source of material for breeding improved varieties.

[B] Biodiversity is essential for stable and healthy ecosystem. If there is a loss of a single or few species from a simple ecosystem, there would be catastrophic because of the lack of alternatives. Biodiversity serves as an effective instrument to ensure optimum utilization of abiotic resources. In the moist tropics of richest biodiversity, decomposition of organic matter and mineralization are very rapid and thus all the available nutrients are absorbed quickly.

[C] Biodiversity has the great aesthetic & cultural values. Examples of aesthetic values include ecotourism, bird watching, wild life, pet keeping, gardening etc.

Threat to Biodiversity

Over-exploitation of natural resources due to increased never-ending human desires and sometimes natural calamities are the major causes for the loss in biodiversity. These important factors are-

a) **Destruction of habitat :** It is the primary reason for the loss of biodiversity. Population explosion, rapid industrialisation, felling of trees, urbanization, commercialisation of agriculture etc are the various causes for the destruction of natural habitat of species. In many countries, particularly on islands where human population density is high, most of the original habitats have been destroyed. In tropical Asia, fully 65% of the wildlife habitat is lost of which 80% in India. The causal are the large industrial and commercial activities like mining, cattle ranching, fishing, forestry, plantation, agriculture, manufacturing and dam construction.

b) **Pollution :** Pollution of various degrees disturbs the balanced ecosystem. Eutrophication (nutrient enrichment) due to water pollution drastically reduces the species diversity. The most subtle form of habitat degradation is environmental pollution due to pesticides, industrial chemicals & wastes, emission from factories & automobiles and sediment deposits from eroded hill sides.

c) **Natural calamities :** Earthquakes, forest fires, volcanic eruptions, tsunamies, floods, drought, epidemics etc. Sometimes cause serious loss to the plant and animal life.

d) **Exotic species :** Three main factors i.e. European colonisation, horticulture & agriculture, and accidental transport are responsible for introduction of exotic species. Sometimes exotic species have large impact especially in island ecosystems. Dodo, a flightless bird of Mauritius, was wiped out due to destruction of their eggs by pigs introduced in the country. In 1859 introduction of European rabbit in the Australia by a farmer for game caused an ecological imbalance due to removal of biological control. Water hyacinth introduced

in India now causes a serious threat to the aquatic species in lakes and ponds. Due to *Lantana camara*, indigenous plants are suppressed.

e) Shifting cultivation/swidden Agriculture/Jhum cultivation.

Extinction of Species

Extinction is the natural process where species have disappeared and new ones have evolved over the long geographical history of our earth. There are three types of extinction processes:-

a) **Natural extinction** : With the change in environmental conditions, some species are disappeared and some are evolved according to the changed condition some species were lost in the geological past is categorised under natural background extinction.

b) **Mass extinction** : There were several geological period of earth when a large number of species became extinct because of catastrophes. Such mass extinction occurs in millions of years.

c) **Anthropogenic extinction** : Such extinction is due to never ending human desires which deplete biodiversity severely only because it occurs in a short period of time.

The characteristics of species susceptible to extinction are

i) Large body size viz. Bengal tiger, lion, elephant.

ii) Small population size and low reproductive rate viz. Blue whale, giant panda.

iii) Feeding at high trophic levels in the food chain e.g. Bengal tiger, Bald eagle.

iv) Fixed migratory routes and habitat e.g. Blue whale, whooping crane.

v) Localised and narrow range of distribution e.g. woodland caribou, many island species.

The species which are threatened with extinction are categorised under :-

a) Vulnerable species means such species are facing a high risk of extinction in the wild in the medium term future.

b) Endangered species means such species are facing a very high risk of extinction in the wild in the near future.

c) Critically endangered : such species are facing an extremely high risk of extinction in the wild in the immediate future.

d) Extinct in wild : When exhaustive surveys are failed to record such species in wild.

e) Extinct : when the last surving individual has died.

Red Data Book

The world conservation union (formerly called international union for the conservation of nature and natural resources IUCN) with headquarter at Gland, Switzerland, is the premier coordinating body for international conservation efforts. The red data book published by the survival service commission of IUCN in 1970 listed the endangered species of plants and animals. According to this book, around 20,000 species are endangered all over the world. IUCN published the book 'IUCN Plant Red Data Book' in 1978 and the book 'IUCN Red list of Threatened Animals' in 1988. According to IUCN(2000) 11,046 species of plants and animals are facing high risk of extinction. A rare flightless bird, Kago in New Caledonia, a primitive wild ox from southern Asia and the Orinoco River crocodile are near extinction. On a global basis, the IUCN estimated that about 10% of the world's vascular plant species (i.e. 20000-25000 species) are threatened.

According to IUCN (1984, 1988), to highlight the legal status of rare species for the conservation purpose, there are five main conservation categories : 1. Extinct, 2. Endangered, 3. Vulnerable species, 4. Rare species (which have small total no. of individuals, 5. Insufficiently known species.

In India, the problem on threatened plants was first discussed in the 11th technical meeting of the IUCN in 1969. In 1980, the Botanical Survey of India (BSI) published a booklet named Threatened plants of India- A state of the Art Report. In 1984, BSI published a book named the Indian plant red data book-I having 125 Data sheets of flowering plants and edited

by S.K. Jain & A.R.K. Sastry. Several other researchers also worked on threatened and endemic plant species and published different volumes of Red Data Books e.g. Vol.I of Red Data Books on Indian Plants edited by M.P.Nayar and A.R.K. Sastry was published by BSI in 1987, which includes 235 vascular plant species of Indian flora. Vol.II of the same editors in 1988 having 192 Data sheets on threatened vascular plants & Vol.III of the same editors in 1990 having 195 threatened taxa of Indian flora.

Biodiversity in India

India is one of the twelve mega-biodiversity countries of the world. On the basis of survey of about 2/3rd of the geographical area of the India the ministry of forest & environment reported (GOI, 2000) that India have about 45,000 plants and 77,000 animals species representing about 7% of world flora and 6.5% of the world fauna respectively representing about 6.5% of the global biodiversity. About 5000 species of flowering plants belonging to 141 genera and 47 families had birth in India. Our country is a source of traditional crop varieties ranking first amongst the 12 regions of diversity of crop plants and 7th so far in the contribution of agricultural species. India is the origin place of 166 species of crop plants and 320 species of wild relatives of cultivated crops.

In India, there are three mega-endemic centres:-

a) **Eastern Himalayas :** 1808 endemic plants from approximately 6000 species.

b) **Western Himalayas :** 1195 endemic plants from 5000 species.

c) **Western Ghats :** 1500 endemic plants from 4000 species.

Biodiversity loss is very severe in agroecosystems. Thousands of wild crop varieties have been replaced by a few hybrid species. This resulted in the loss of genetic resources. Indiscriminate use of agro-chemicals has reduced the microbial flora and fauna.

Endangered species in India

According to the red data book of IUCN, more than 1000

creatures are threatened with extinction e.g., all species of rhinoceros, Royal Bengal, and Siberian Tigers, mexican grizzly bear, wolf, mountain gorilla, Arabian oryx and Asiatic lion. In India, nearly 450 plant species are either endangered, threatened or rare. Some animal species have been identified as endangered ones. They are Hoolock gibbon (the only ape in India), some sp. of macaque, Nilgiri langur, Indian wolf, sloth bear, red panda desert cat, Great Indian one-horned rhinoceros, Asiatic two-horned rhinoceros, musk deer, wild yak, Gangetic dolphin, swans, geese, many hawks, the great Indian bustard, the estuarine crocodile, gharial, Indian python, Indian salamander, a large hermit crab, Indian vultures etc.

Indian Vultures

The oriental white-backed vulture, once thought to be the commonest bird of prey in the world, has lost 99.9% of its population since 1992, (study by Bombay Natural History Society). Numbers of long-billed and slender-billed vultures have together fallen by almost 97% in the same period. The no. of oriental white backed vultures is down to 11000 as compared to around 30 million across northern India in the early 1990s. The population of long-billed and slender billed vultures has dropped to around 45000 and 1000 birds respectively. All three species could be down to a few hundred birds or less across the whole country and thus become functionally extinct in less than a decade.

Dr. Oak of Washington found that the above three species of the vultures in India & Pakistan feed on the dead cattle first because of their aggressive nature. Scientists found that an anti-inflammatory drug for cattle especially Diclofenac Sodium increases the quantity of uric acid in the vultures and ultimately causes the kideny failure. Therefore, the use of veterinary diclofenac has been banned since 2006. But also a version of diclofenac developed for human use is being utilised by farmers to treat livestock. Because it's an effective drug vets and farmers are just buying it from pharmacies for use.

The removal of vultures from Indian and Pakistan ecosystem causes the dramatic impacts on the environment. The white

backed vultures was the primary scavenger. Now Piles of carcases are not being eaten up, increasing the risk of contamination of water bodies. Other scavengers such as rats and feral (wild) dogs are also moving in. Besides the declining numbers are also a matter of concern for the Parsi communities who leave their dead body out in the open space to be consumed by vultures. One of Indian's three captive breeding centres enjoyed its first success when two oriental white-backed vulture chicks were born.

Hot spots /Hotspot

Biodiversity hot spots were originally identified by Norman Myers in 1990s to designate an area which faces serious threat from human activities and supports a unique biodiversity with representatives of evolutionery process of speciation & extinction. It is the geographical zone or ecological niche with a large no. of endemic plants. There are 20 hot spots of biodiversity all over the world, a habitat of about 49,550 endemic species of higher plants representing about 20% of the world's total plant species. The no. of hot spots in the world has now increased to 34, accounting for just 1.4% of the world's land and support 60% of species on earth. India has four hot spots viz., North-East, Eastern Himalayas, Western Ghats & Andaman & Nicobar island. In addition to these, special hot spots are the mangroves, wetlands & swamps.

Conservation of Biodiversity

To conserve rare and threatened species it is necessary to protect their natural habitats and specific measures are taken to prevent their unplanned exploitation & illegal trade. The method of conservation of biodiversity is grouped into two heads :-

(a) In-situ conservation i.e. the conservation in its natural habitat.

(b) Ex-situ conservation i.e. the conservation outside the natural area.

(a) In-situ conservation

Such measures which conserve the genetic resources through their maintenance within natural or human made ecosystems in which they occur. Such natural habitats are declared as protected areas.

Yellow Stone Park (Y.S.P.) is the first National Park of the world and established in 1872 in America. Hailey National Park is the First national park of India established in 1936. A protected area is such area of land and or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources and managed through legal or other effective means. The protected areas are :-

1) Wildlife sanctuaries
2) National parks
3) Biosphere reserve
4) World heritage sites/sacred groves/ National monuments/ cultural landscapes

Wildlife sanctuary - is an area constituted by competent authority in which killing and capturing of any form of wild life is prohibited except with permission and the boundaries and character of which are sacrosanct. By the year 2000, there were 490 sanctuaries in India.

National Park - is a reserve of land, usually owned by a national government that is protected from most human development and pollution. In India there were 88 National Parks(NP) by the year 2000.

Biosphere Reserve - is an area of terrestrial and coastal ecosystems which are internationaly recognised within the framework of UNESCO's [United Nations Educational, Scientific & Cultural Organisation] Man and Biosphere (MAB) Programme. Objectives of Biosphere Reserves-

i) To conserve diversity and integrity of plants, animals & micro organisms.
ii) To promote research on ecological conservation & other environmental aspects.
iii) To provide facilities for education, awareness and training.
iv) To develop database and to make plans to conserve key species.
v) To establish research stations and to implement social welfare actvities.

Table :- Difference between National Park, Sanctuary and Biosphere reserve

	National Park	Sanctuary	Biosphere reserve
1.	Hitched to the habitat for particular wild animal species like tiger, lion, hangul, rhino etc.	Generally species-oriented as citrus, pitcher plant, Great Indian Bustard.	Not hitched to anyone, two or more species, but to the whole ecosystem i.e. totality of all forms of life i.e. ecosystem-oriented.
2.	In India, the size range is 0.04 to 3162 sq. km. Most common (in about 40%) is 100 to 500 sq. km. In 15% is 500 to 1000 sq.km.	Size range is 0.61 to 7818 sq. km. Most common (in about 40%) is 100 to 500 sq. km. In 25% is 500 to 1000 sq. km.	Size range over 5670 sq. km.
3.	Boundaries circumscribed by legislation.	Boundaries sacrosant.	Boundaries circumscribed by legislation.
4.	Except the buffer zone, no biotic interference.	Limited biotic interference.	Except the buffer zone, no biotic interference.
5.	Tourism permissible.	Tourism permissible.	Tourism normally not permissible
6.	Research and scientific management lacking.	Lacking.	Managed
7.	So far no attention to genepools and conservation.	So far no attention.	Attention given

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Table:- Important National Parks (N.P.) and Sanctuaries

Name of N.P. & Sanctuary	District	Total Area	Main Species found
Andhra Pradesh			
Pakhal	Warangal	860	Tiger, samber, panther, chita, blue bull etc.
Tadwai	Warangal	803	Tiger, panther, gaur, Jungal cat, samber, black buck etc.
Pocharam	Medak	129.5	Panther, Chital, Chinkara, peafowl, water birds etc.
Kawal	Adilabad	616	Tiger, panther, gaur, samber, chital, black buck, wild bear, sloth bear etc.
Kolieru	Elleru	673	Pelicans, flamingo, heron, painted storks, avocet, teals and terns.
Melapattu bird	Nellore	16	Grey pelican, heron, cormorants, teals ducks etc.
Kinnersani	Khamman	635.40	Tiger, panther, wolf, chital, samber, nilgai, sloth bear, gaur etc.
Papikonda	E. Godawari, W. Godawari Khamman	591	Tiger, panther, wild dog, hyena, jackals, gaur, wolves, antelops, chital, samber and nilgai etc.
Coringa	E. Godavari	235	Estuarine crocodile, otter, fishing cat, jackal, sea gull, pelican, stork, heron, flamingo.
Nagarjun Sagar	Guntur,Srisailam, Najgonda, Kurnool Mahabubnagar	3568	Tiger, panther, sloth bear, nilgai, black buck, fox, wild bear, chital, samber, wolf, crocodile etc.
Pulicat	Nellore	500	Flamingos, pelicans, ducks, teals, stork, crane, heron.
Arunachal Pradesh			
Namdafa	Tirap	1807.82	Tiger, panther, snow-leopard..clouded leopard, golden cat, binturang, wild baffalo, wild dog, gaur, Iranian bisan, sambar, hog deer, barking deer, elephant, slothbear, python, king kobra, Indian Kobra, monitor, lizard and many kinds of birds.
Pakkui	Kameng	861.95	Elephant, gaur, samber, hog deer, barking dear, python.
Assam			
Garampani	Diphu	430	Elephant, wild buffalo, leopard, langur, hoolock
Kaziranga (N.P.)	Jorhat	430	One horned rhinoceros, wild buffalo, gaur, elephant, wild bear, leopard cat, otter, swamp deer, civet cat, tiger, hog deer, sambar, python, pelican patridge, floricans

Lakhawa	Nawgang	70	Rhinoceros, wild buffalo, swamp deer, hog deer, water duck, cormorants.
Manas (Tiger Sanctuary)	Barpeta	80	Elephant, tiger, panther, gaur, wild buffalo, great Indian one-horned rhinoceros, golden langur, otter, swamp deer, hog deer, pigmi hog, florican, civet cat etc.
Sonai-Rupa	Tezpur	195	The Great Indian one-horned rhinoceros, elephant, wild buffalo, sloth, bear, wild dogs, wild boar, sambhar, swamp deer, barking deer, leopard, tiger, hornbill, imperial pigeon etc.
Bihar			
Bhimbandh	Monghyr (Munger)	681.90	Tiger, leopard, sambar, chital, wild boar, wolf, water bird etc.
Gautam Buddha	Gaya	259.50	Tiger, leopard, sambar, chital, barking deer, peat-fowl etc.
Kaimur	Rohtas	1342.22	Tiger, leopard, chinkara, sambar, nilgai, crocodiles
Jharkhand			
Hazaribagh	Hazaribagh	86.25	Tiger, leopard, sambar, chital, nilgai, wild boar, wild cat, fowl etc.
Mahudaur	Daltonganj	63.25	Tiger, leopard, wolf, chital, barking deer, wild boar etc.
Dalma	Singhbhum	193.22	Elephant, leopard, wild boar, mouse dear, barking deer, sloth bear.
Palamu	Daltonganj	979.27	Elephant, panther, leopard, wild boar, barking deer, gaur, chital, peat-fowl etc.
Bamiaburu	Singhbhum	129.50	Tiger, panther, elephant, wild boar etc.
Koderma	Koderma	176.12	Tiger, leopard, sloth bear, sambar, chital, four horned antelope.
Goa, Daman & Diu			
Mollem	Goa	240	Gaur, sambar, mouse deer, barking deer, panther, flying squirel, porcupine, cat, ant-eater, fowl etc.
Gujarat			
Gir (N.P.)	Junagarh	140.40	Asiatic lion, panther, stripped Hyena, Sambar, nilgai, chital, four horned antelope, chinkara, wild boar, crocodile etc.
Valavadar (N.P.)	Bhavnagar	17.83	Black buck, wolf etc.
Gir	Junagarh	1412.13	Asiatic lion, panther, stripped hyena, four horned anti lope, chinkara, wild boar, crocodiles etc.
Naisarovar (Bird sanctuary)	Ahmedabad	115	Water birds

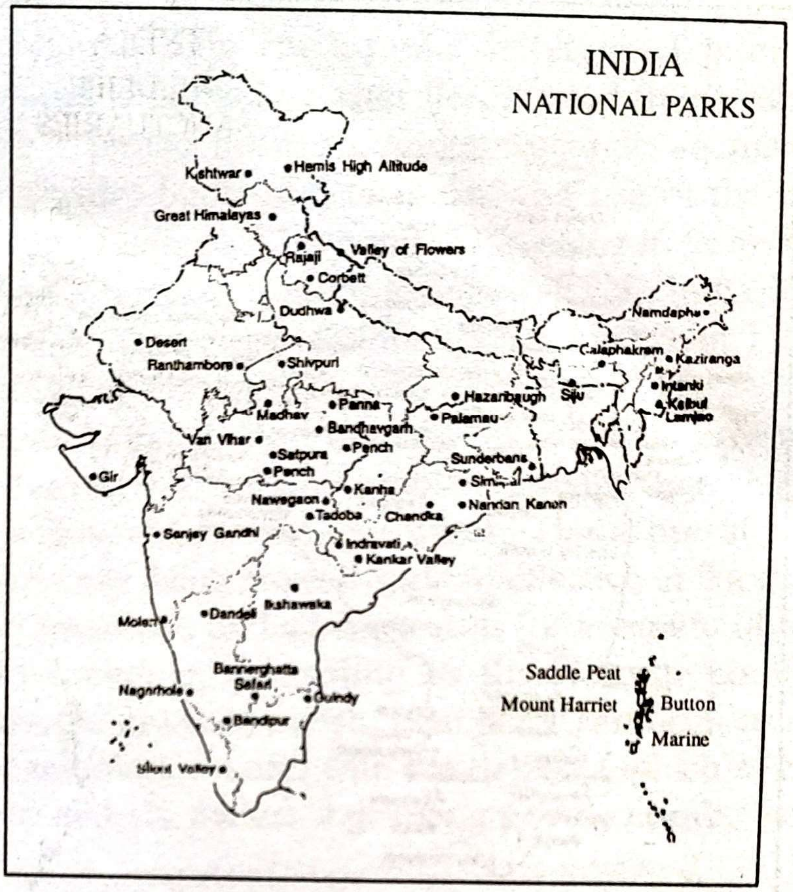
Wild Ass Sanctuary)	Surendra Nagar	4840.89	Wild ass, nilgai,wolf, chinkara.
Purna	Dangs	299.43	Tiger, panther, leopard, cat, jungle cat, jackal, fox, four horned antelope, wild pig, chital, sambar, bonnate macaque.
Haryana			
Sultanpur (Lake birds)	Gurgaon	1.2	Sarus crane,spot bills, ruddy shel drakes etc.
Jammu & Kashmir			
Dachigam	Srinagar	142.45	Leopard, black bear, brown bear,baboons, serow, musk deer, hangul.
Raj Prian	Anantnag	53.1	Brown bear, black bear, musk deer, serow, hangul etc.
Himanchal Pradesh			
Rohia (N.P.)	Kullu	197.8	Musk deer, ibex, serow, Himalayan brown bear, snow-leopard, tragopan, snow pigeon, snow cock etc.
Tundah	Chamba	64.2	Brown bear, musk deer, black bear,tahr, gorl, ibex, serow, monal, tragopan, snow cock, chakor and chir, snow leopard, panther fox flying fox, weasel etc.
Kugti	Chamba	118.3	Musk deer, brown-bear, black bear, tahr goral,serow, ibex monal, tragopan, snow cock, kalij, chakor and chir snow leopard, panther, civet, fox, flying fox, weasel etc.
Nargu and Winch	Mandi	278.4	Musk deer, black bear goral, serow, koklesh and chir, panther, snow leopard, martens, civet, fox, flying fox etc.
Gobind Sagar	Lilaspur	100.4	Duck, teal, goose, crane etc.
Sri-Naina	Lilaspur	163.4	Sambar, black bear, barking deer,wild boar, Nilgai, red jungle fowl, patridges, panther, snow leopard, martens, civet, fox, flying fox.
Derang	Kinnaur	167.4	Blak bear, goral serow,monal, kalij, chakor. koklash, panther, civet flying fox, martens etc.
Talra	Simla	76.2	Goral, black bear, musk deer, sambar, chakor koklash monal, panther, flying fox, civet, martens.
Raksham and Chitkul	Kinnaur	138.3	Goral,gharal, black bear, brown bear, monal kiklash, snow cock, chakor, panther, fox, martens, flying fox.
Lipa Asrang	Kinnaur	1091	Monal, goral, bharal, chakor, koklash, snow cock, panther, fox, flying fox etc.

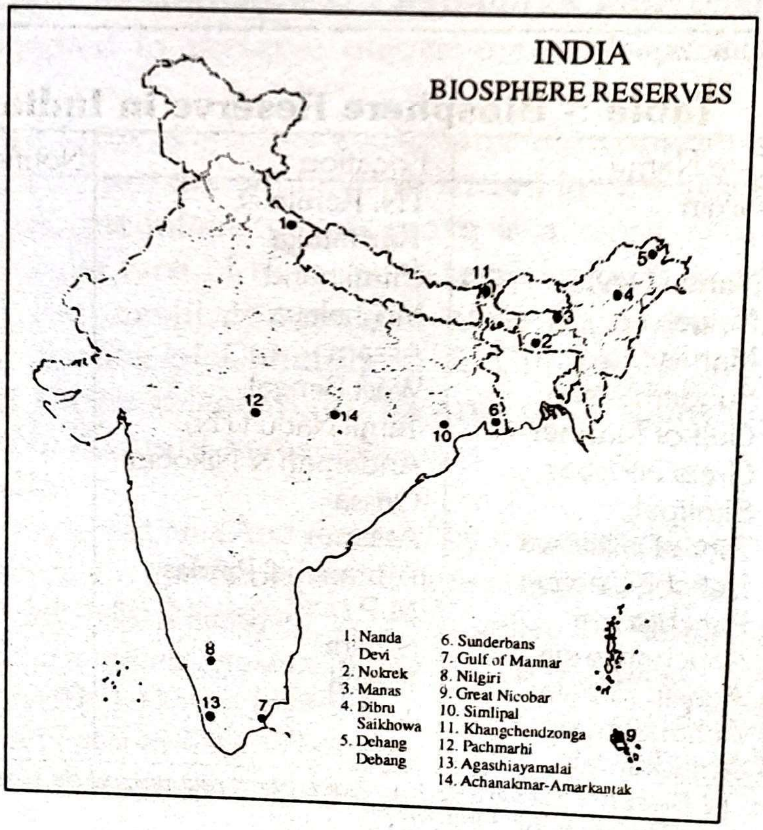
Simbalbara	Sirmur	55.4	Sambar, goral, barking deer, wild boar, kalij, pea fowl, red jungal fowl, patridge, panther, fox, chital, monal etc.
Kanswar	Kulu	54.3	Tahr, serow, goral, black bear, chakor-koklash, chir, patridges, panther civets, martens, flying fox.
Karnataka			
Bandipur (N.P.)	Mysore	874.20	Elephant, tiger, gaur, sambar, chital, barking
(Tiger sanctuary)	deer, wild dog, wild boar,		jackal, sloth bear, panther, four horned antelope, malabar squirrel, jungal fowl, patridges, green pigeon, bush quail etc.
Bannerghatta (N.P.)	Bangalore	104.20	Elephant, sloth bear, chittal, barking deer, grey patridges, bush quail, jungle fowl etc.
Nagarhole (N.P.)	Coorg	571.55	Elephant, tiger, panther, chital, sam barsloth bear, jungle fowl, patridges etc.
Someshwar	South Kanara	844.8	Chital, gaur, sambar, panther, tiger, sloth bear, wild dog etc.
Brahmagiri	Coorg	181.28	Tiger, panther, sambar, chital, barking deer, sloth bear, cobra, flying squirrel, malabar squirrel, civet cat, mouse deer etc.
Malkote	Mandya	49.82	Panther, wolves, sloth bear, black buck, hare, porcupines, wild boar, etc.
Ghatprabha (bird sanctuary)	Belgaum	29.78	Egret, cormorant, heron etc.
Tungabhadra	Bellary	224.22	Chinkara, panther, chital, pig. black buck, four horned antelope, fox, sand grouse, florion, great Indian bustard, sloth bear samber etc.
Rannebennur (Black Buck Sanctuary)	Dharwar	119	Black buck, chital, wolf, hare, great Indian bustard
Biligiri Rangas-wamy	Mysore	324.4	Elephant, gaur, chital, barking deer, sambar, panther, sloth bear
Bhadra	Chikmaglur	492	Gaur, elephant, panther, wild bear, sambar, chital, barking deer, sloth bear
Ranganthitoo bird sanctuary	Mysore	26.70	Open bill stork, white ibis, little egret, cattle darter, carmorant, pond heron, crocodile etc.
Dandeli	Dharwar	874.20	Tiger, panther, elephant, gaur, sambar, chital, wild bear etc.
Kerala			
Eravikulum Rajmallay (N.P.)	Idduki	97	Elephant, gaur, sambar, barking deer, tiger, Panther, civet, jungle cat, Nilgai, langur, wild dogs, nilgiri tiger, imperil pigeon, grey jungle fowl.

Periyar	Idduki	777	Elephant, tiger, panther, wild dog, gaur, sloth bear, nilgai, wild boar, sambar and barking deer.
Parambikulum	Palghat	285	Elephant, gaur, leopard, tiger, sloth bear, nilgai, chital etc.
Madhya Pradesh			
Kanha (N.P.)	Mandla and Balaghat	940	Tiger, panther, gaur, barasingha, chital, sambar, black buck, barking deer, chowsingha, mouse deer, wild dog etc.
Bandhavgarh (N.P.)	Shahdol	105	Tiger, Panther, gaur, chital, sambar, nilgai, chinkara, barking deer, bear, wild boar, many birds.
Shivpuri (N.P.)	Shivpuri	156	Tiger, panther, sloth bear, Hyena, Sfimbar, spotted deer, four horned antelope, black buck, nilgai, chinkara, wild boar, crocodiles etc.
Bori	Hoshangabad	802.89	Tiger, panther, bison, sambar, chital, nilgai, chinkara, barking deer, wild boar, bear etc.
Bagdara	Sidhi	478.9	Panther, black buck, chinkara, sambar, nilgai, wild pig etc.
Pachmarhi	Hosangabad	654.5	Tiger, panther, bear, bison, spotted deer, sambar, barking deer, nilgai etc.
Ratapani	Raisen	530.36	Tiger, panther, sambar, chital, blue bull, chinkara.
Gandhi Sagar	Mandsaur	224.65	Water birds, chital, sambar, chinkara, barking deer etc.
Chhatis Garh			
Kutree wild-Buffalos game Sanctuary)	Bastar	2273.58	Wild buffalo, tiger, panther, sloth bear, nilgai, chital, sambar, wild pigs, barking deer, bison wild dogs, etc.
Tamor-pigle	Sorguga	608.53	Tiger, panther, gaur, chital, sambar etc.
Achankmar	Bilaspur	351.52	Tiger, bison, sambar, chital, boar peacock etc.
Maharashtra			
Todoba (N.P.)	Chandrapur	116.55	Tiger, panther, sloth bear, sambar, chital, nilgai, chinkara etc.
Pench (N.P.)	Nagpur	257.26	Tiger, panther, gaur, sloth bear, sambar, chital, barking deer, four-horned antelope, nilgai, chinkara, pea fowl and jungle fowl.
Nawegaon (N.P.)	Bhandara	133.85	Tiger, panther, sloth bear, gaur, sambar, chital, barking deer, nilgai, migratory birds etc.
Borivali (N.P.)	Bombay	67.98	Panther, sambar, four-horned antelope, mouse deer, wild bear, and langur.

Melghat (Tiger sanctuary)	Amraya	381.58	Tiger, panther, gaur, sloth bear, sambar, barking deer, four horned antilope, wild bear, chital etc.
Yawal	Jalgaon	177.52	Panther, Jungle cat, nilgai, langur, wild dog, sambar, hyena, tiger, chital, chinkara, pea fowl, green pigeon, grey jungle fowl.
Radhanagari	Kolhapur	2072	Gaur, panther, sambar, and several birds.
Manipur			
Reibul Lamiao (N.P.)	Central	25	Brow antelered deer, wild goat and water birds
Meghalaya			
Balpakram	Garo-Hills	85	Elephant, gaur, chital, sambar, wild boar
Mizoram			
Dampa	Aizawl	180	Elephant, tiger, leopard, sambar, barking deer, Himalayan bear, wild boar, leopard cat, King Kobra, python etc.
Nagaland			
Intangki	Kohima	202	Gaur, boar, elephant, barking deer, wild boar, clouded leopard, panther, tiger, pangolin etc.
Orissa			
Chilka	Ganjam and Puri	900	Black buck, chital, sea cow, cranes, ibis, cormorant, egret, flamingo and pelican
Satkosia	Puri, Cuttack & Phulbani	750	Gharial, muggar, tiger, leopard, jungle cat, civet, sloth bear, sambar, chital, nilgai, four-horned antilope, elephant, hornebill, peafowl, jungle fowl and other birds.
Punjab			
Abohar	Ferozepur	228	Black buck, hare, pairidge, grey and black pigeon and doves.
Rajasthan			
Ranthambor	Madhopur	392.20	Tiger, panther, hyena, jungle cat, civet, sambar, chital, nilgai, bear, red spur fowl etc.
Ghana (Bird Sanctuary) or Keolodeo Sanctuary (N.P.) or Bird paradise of Bharatpur	Bharatpur	29	Siberian crane, carmorants, storks, spoon bills, quails, coot, heron, teal, terns etc.
Mount Abu	Sirohi	112.6	Nilgai, sambar, hare, jungle fowl, etc.
Kumbalgarh-Ranakpur Udaipur	Jodhpur	500	Wild bear, sambar, panther, nilgai, wild boar, jungle fowl, red spur fowl.
Sikkim			
Khangchand-Zenda(N.P.)	Gangtok	850	Snow leopard, clouded leopard, marbled cat, civet, bintljrone, Himalayan black bear,

			red panda, Tibetan wild ass, blue sheep, serow, takin, musk deer, green pigeon, partridge etc.
Tamil Nadu			
Guindy (N.P.)	Madras	2.8	Chital, black buck and a snake park
Mudumalai	Nilgiris	321	Elephant, gaur, chital, sambar, tiger, panther, sloth bear, wild dog etc.
Amarmalai	Coimbatore	958	Gaur, elephant, chital, sambar, tiger, panther, wild dog, sloth bear etc.
Uttarakhand			
Corbett (N.P.)	Nainital,Garhwal	525	Elephant, tiger, panther, sloth bear, nilgai, chital, wild bear, porcupine, peafowl, partridge, red Indian jungle fowl, four-horned antelope.
(**First National Park** (N.P.) of India, Previous name Hailey NP or Ramganga NP.)			
Govind Pashu Vihar	Uttar Kashi	953	Brown and black Himalayan bear, snow leopard, bharal, musk deer, tahr, serow, goral, panther, sambar, wild boar, monal, green pigeon etc.
Kedarnath	Chamoli	957	Brown and black bear, snow leopard, Bharal, musk deer, tahr, serow, goral, panther, sambar, pheasant, snow pigeon, kokla, green pigeon, monal etc.
Chila	Garhwal	249	Tiger, panther, bear, elephant, chital, sambar, nilgai, etc.
U.P.			
Dudwa (N.P.)	Lakhimpur Kheri	500	Tiger, panther sloth bear, sambar, swamp deer, chital, hog deer, barking deer, nilgai, peafowl and jungle fowl, partridge etc.
Chandraprabha	Varanasi	78	Tiger, panther, sambar, Indian gazelle, sloth bear, nilgai, pea fowl, parlridges, sand grouse etc.
Katarniaghat	Bahraich	400	Tiger, panther, sambar, bear, chital, black buck etc.
Ranipur	Banda	230	Tiger, panther, wild cat, sambar, hyena, fox, jackal, chital, chinkara, black buck etc.
West Bengal			
Lothian Island	24 Pargana	38	Wild pigs, chital, otter, estuarine crocodiles, Gangetic dolphin, water birds etc.
Holiday Island	24 Parganas	5.95	Royal Bengal tiger, chital, water birds etc.
Sajnakhali	24 Parganas	362.40	Tiger, wild boar, chital, coromant; open bill strokes, snake birds, white ibis, purple, heron, grey heron, green bitter, pelican etc.
Jaldapara	Jalpaiguri	115.53	Rhino, elephant, tiger, leopard, wild boar, gaur, barking deer, hog deer, sambar and a variety of birds.
Mahanadi	Darjeeling	127.22	Tiger, elephant, gaur, sambar, hog, wild boar, gibon and a variety of birds.
Sunderbans	24 Parganas	2585	Tiger, varieties of deer, wild boar, estuarine crocodile, Gangetic dolphin.


INDIA
NATIONAL PARKS
Kishtwar
Hemis High Altitude
Great Himalayas
Rajaji
Valley of Flowers
Corbett
Dudhwa
Namdapha
Desert
Ranthambore
Shivpuri
Calaphakram
Kaziranga
Intanki
Keibul Lamjao
Hazaribaugh
Siju
Madhav
Panna
Palamau
Bandhavgarh
Van Vihar
Satpura
Pench
Pench
Sunderbans
Gir
Simlipal
Kanha
Nawegaon
Nandan Kanan
Tadoba
Chandka
Sanjay Gandhi
Indravati
Kankar Valley
Ikshawska
Mole:m
Dandeli
Bannerghatta Safari
Saddle Peat
Mount Harriet
Button
Nagarhole
Guindy
Marine
Bandipur
Silent Valley


INDIA
BIOSPHERE RESERVES
1. Nanda Devi
2. Nokrek
3. Manas
4. Dibru Saikhowa
5. Dehang Debang
6. Sunderbans
7. Gulf of Mannar
8. Nilgiri
9. Great Nicobar
10. Simlipal
11. Khangchendzonga
12. Pachmarhi
13. Agasthiayamalai
14. Achanakmar-Amarkantak

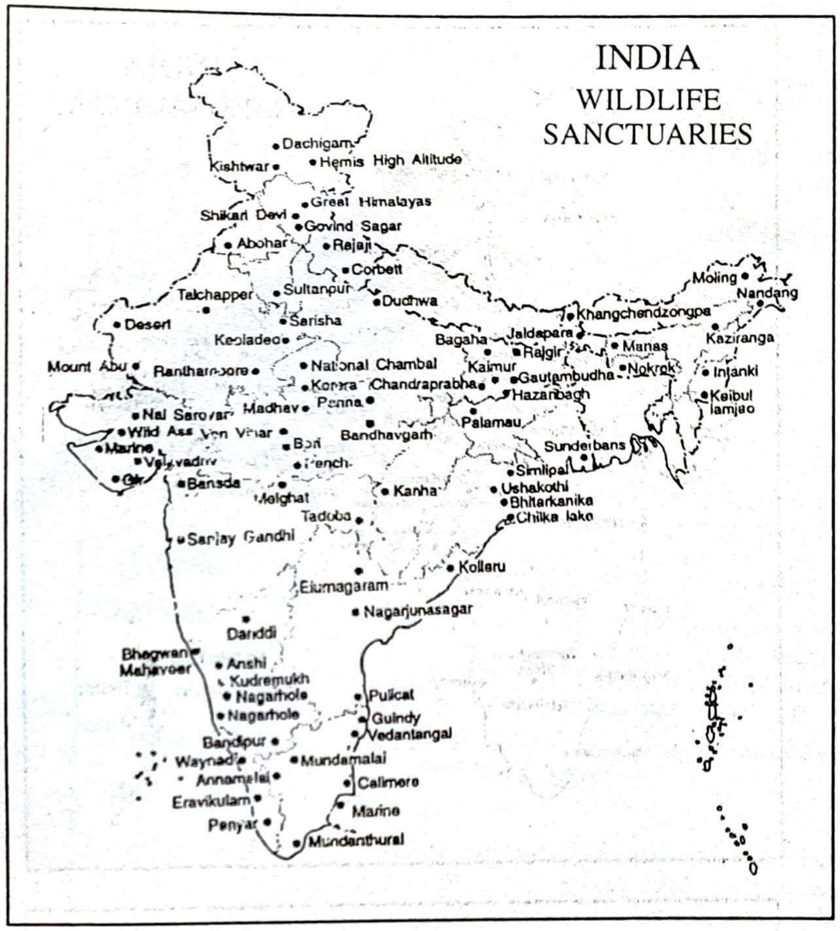


Table :- Biosphere Reserve in India

S.No.	Site Name	Location	Notification Year
* 1.	Nilgiri	TN, Kerala & Karnataka	1986
* 2.	Nanda Devi	Uttrakhand	1988
3.	Nokrek	Meghalaya	1988
4.	Manas	Assam	1989
* 5.	Sunderbans	West Bengal	1989
* 6.	Gulf of Manner	Tamil Nadu (TN)	1989
7.	Great Nicobar	Andaman & Nikobar	1989
8.	Simlipal	Orissa	1994
9.	Dibru-Daikhowa	Assam	1997
10.	Dehong-Debang	Aruranchal Pradesh	1998
11.	Panchmarhi	M.P.	1999
12.	Kanchanjanga	Sikkim	2000
13.	Agasthyamalai	Kerala	2001
14.	Achanakmar Amarkantak	M.P.	2005

** Out of 14 Biosphere reserves, four have been recognized on world Network of Biosphere Reserves by UNESCO.*

Ramsar sites

It represents different aquatic habitats of international importance and is named so after the Ramsar (Iran) convention held in 1971 to protect the ecosystem of wetlands, aquatic species, specially the water birds, and to make wise use of the wetlands for the benefit of people. This convention came in to existence in 1975 and India became a party to it in 1981. In India a total of 16 Ramsar sites have been identified, covering about 1.1 million hectare, including the Andaman & Nicobar Islands.

Wetlands are such land transitional between terrestrial and aquatic system where the water table is usually near the surface and land is covered by shallow water. These are life support systems for people living around and are effective in flood control, waste water treatment and winter resorts for a variety of birds for shelter and breeding. According to the Ramsar convention, wetlands are the areas of marsh, peat lands, artificial or natural, brackish or salt marine water with the depth of which at low tide does not exceed six meters e.g. mangrooves, corals, estuaries, lakes etc.

National Monuments & Landmarks - are often smaller areas designated to preserve unique areas of special national interest.

Sacred Groves - Some ecosystems are considered sacred and preserved since ancient times as sacred forests groves, lakes, ponds, caves, mountains etc. A grove is a small area of land having particular type of trees. Such sacred groves are Bamboo groves of Rajbanshi community of W.B., Orans of West Rajasthan, Sarnas of Chhatisgarh & Chhota Nagpur, Maw-Bukhars of Khasis (Meghalaya), Devrais of Maharashtra, Kovil Kadu of T.N., Kuvus of Kerala etc.

Silent Valley

It is a protected area and reserved by the silent valley protected area (Conservation and Ecological Balance) Act, 1979. It is situated in the Kundali hills (Nilgiri) of Western valley of Kerala. It is the only tropical evergreen forest of India which is unaffected by human activities. In 1984 (15th November), the whole silent valley was declared as National Park. The silent valley is considered as the central area of Nilgiri Biosphere Reserve.

[B] Ex-situ conservation

It involves maintenance and breeding of endangered plant and animal species under partially or wholly controlled conditions in botanical garden (arboreta/Herbal garden), nurseries, zoos, conservation stands and gene bank, seed (germplasm) bank, pollen bank, semen/ovum bank, tissue culture and DNA banks.

Germplasm banks/Gene banks - Such banks are established for ex-situ conservation of the species and include botanical gardens/arboreta, animal zoos, genetic resource centres, culture collections etc. In plant species, seeds, pollen grains, vegetative propagative parts, tissues etc are collected and stored in such germplasm banks. IPGRI (International Plant Genetic Resources Institute, Rome) has come up for ex-situ conservation of plant genetic resources. In our country on Indo-US project on plant genetic resources was taken up in 1988 to establish a National Gene Bank. Seeds of most plant species are stored in cold, dry conditions in seed banks for long periods and then later germinated to form new plants.

China & USA have set up research centres for endangered species. China has recently established IVF (in vitro Fertilization) facility at the embryo engineering laboratory for giant pandas and other endangered species in Chengdu. In our country the third of its kind in the world, a research centre for the conservation of endangered species has been set up near Nehru Zoological Park, Hyderabad. One of the objectives of this centre is to establish gene banks and improve the reproductive capacity of endangered animals by various assisted reproductive technologies like electro-ejaculation, IUI (Intro-Uterine Insemination), IVF, GIFT (gamete intrafallopian tube transfer), ZIFT (Zygote intra fallopian tube transfer) and ET (embryo transfer).

Environmental Laws

The united Nations conference on Human Environment, held at Stockholm (Sweeden) in 1972 (Stockholm Conference) was the first major step from the U.N. to address the growing problem of environmental degradation and need to conserve and protect the human environment at international level. The late Mrs. Indira Gandhi, the then Prime Minister of India participated in this

conference and emphasised that the removal of poverty is an integral part of the goal of an environmental strategy for the world.

Brundtland Commission laid down the concept of sustainable development in 1980. In 1980, IUCN in collaboration with UNEP (United Nations Environment Programme), WWF (World Wildlife Fund) and UNESCO (United Nations Educational, Scientific and Cultural Organisation) developed a strategy on the use of various resources. The strategy aimed at the sustainable utilization of species and the ecosystems which support millions of communities as well as industries. After the strategy United Nations conference on environment and development was held in **Rio de Janerio** in 1992. This conference was also known as **Earth Summit**. The convention on Biodiversity **(CBD)** was tabled at the conference, and came into force at the end of 1993. India became a party of it in 1994 because India is one of the 12 so called mega biodiverse countries of the world. World summit on sustainable Development (WSSD) was held in 2002 in South Africa.

After Stockholm Declaration of 1972, Indian Parliament inserted two Articles 48A and 51A in the constitution of India in 1976. Article 48A-rightly directs that the state shall endeavour to protect and improve the environment and safeguard forests and wildlife of the country. Similarly, clauge(g) of Article 51A imposes a duty on every citizen of India to protect and improve the natural environment including forests, lakes, river and wild life and to have compassion for living creatures. But in India, the first codified law which initiated a series of law dates back to 1873 when British rulers enacted **Madras Wild Elephant Preservation Act** and the **All India Elephant Preservation Act, 1879** which were closely followed by the **Birds Protection Act 1887**. The constitutional provisions of our country are backed by a number of laws, rules and notifications. The **Department of Environment** was established in **1980** to ensure a healthy environment which later become the **Ministry of Environment & Forests in 1985**. The **Environment (Protection) Act 1986** came into force soon after the Bhopal Gas Tragedy. **Biological Diversity Act, 2002** was enacted by our parliament to provide for conservation of biological diversity, sustainable use of its components and equitable sharing of the benefits arising

out of the use of biological resources and for matters connected therewith or incidental thereto.

The **National Biodiversity Authority (NBDA)** has been set up at Chennai in 2003 under the Biological Diversity Act, 2002 to deal with requests for access to genetic resources by foreigners, and to manage requests to transfer the result of any related research out of India. National Environment Policy, 2006 recognises the mangroves and coral reefs as important coastal environmental resources. **Mangroves** are such plants who survive on high salinity, tidal extremes, strong winds, high temperature and muddy anaerobic soil. Mangroves protect coastal communities from cyclones and coastal storms. India is the home to the best mangroves in the world e.g. Sunderbans.

Coral Reefs are shallow water tropical marine ecosystems, characterised by high biomass production and rich floral and faunal diversity. Four coral reefs i.e. Gulf of Mannar, Andaman & Nicobar Islands, Lakshadweep islands & Gulf of Kutchchh are identified for conservation & management.

A no. of wildlife acts have been made from time to time, by state as well as union government for protection of wildlife viz.,

1) Madras Wild Elephant Preservation Act, 1873.
2) All-India Elephant Preservation Act, 1879.
3) The Wild Birds and Animals Protection Act, 1912.
4) Bengal Rhinoceros Preservation Act, 1932
5) Indian Board for Wildlife, 1952
6) Prevention of Cruelty to Animals Act, 1960
7) Wildlife (Protection) Act, 1972
8) National Wildlife Action Plan, 1982.

Wildlife (Protection) Act, 1972 was passed to provide greater attention to conservation of wildlife. This Act was amended in 1991 to make more comprehensive and provide for setting up of zoo authority of India, oversee management of zoos in the country, protection of rare and endangered spp. and also empowering individuals to file complains against offenders. The Wildlife (Protection) Act has been again amended in the year

2002. In this amendment, National Wildlife Board has been constituted as statutory board with PM as the chairman. There is also provision for Community Reserve and Conservation Reserve.

Indian Forest Act was passed in the year 1865 in which there were provision of cultivation and grazing on forest land and protection of trees and prevention of forest fires. This act was revised in 1878 in which provision of 'Reserve' and protected forest made. Rights in reserve forests were extinguished and in protected forests they were defined and recorded at the time of settlement.

This Act was again revised and made a comprehensive Act in the year 1927 which provides for constitution of Reserved Forests, Protected Forests, Village Forests, Demarcation, Transit of Forest Produce, drift wood realization of dues / penalties, cattle trespass etc. Indian forest Act, 1927 (IFA) with various amendments by various states according to the demand of situation, administration, and technical requirement of a particular state, is currently applicable throughout the country. The Tree Protection Act, 1976 for protection of trees in rural and urban areas of hills was passed to regulate felling of trees on private land in UP. IFA, 1927 is the principal legislation for management of forests in Uttarakhand also. This Act has been amended to control illicit activities in the forest by empowering forest office to consfiscate STP (Store, tools, plants) used for committing offence and enhancing the scale of fire/imprisonment. The forest (conservation) Act was passed in 1980 and ammended in 1988.

*

3 Environmental Pollution

Pollution is such

a) an undesirable change

b) in the physical chemical or biological characteristics

c) of air, water or soil i.e. abiotic components

d) which is harmful

e) to the biotic component or components of biosphere.

Biosphere

The earth planet alongwith the atmosphere (air, land, water) that sustains life is called biosphere.

Pollutant is such substance which causes pollution.

Pollution is a man-made problem, mainly of developed countries. Unlimited exploitation of nature disturbed the delicate ecological balance between living and non-living component of the biosphere. The so called good people have been in a race to exploit every bit of natural resources to convert them into goods for their comfort. Thus pollution is a necessary evil of all such development. The various environmental pollutants are :

a) Deposited matter : soot, smoke, tar, dust grit etc.
b) Gases : Oxides of nitrogen (NO, NO_2), sulphur (SO_2), carbon monoxide, halogens (Cl, Br, I)
c) Acid droplets : H_2SO_4, HNO_3 etc.
d) Metals : Mercury (Hg), lead (Pb), Iron (Fe), Zinc (Zn), Nickel (Ni), Cadmium (Cd), Chromium (Cr) etc.
e) Fluorides : Silicon tetrafluorides
f) Agrochemicals : Biocides (pesticides) & fertilizers.
g) Complex organic substances: Benzene, ether, acetic acid, benzpyrenes etc.
h) Photochemical oxidants : Photochemical smog, ozone,

peroxyacetyl nitrate (PAN), Peroxy benzoil nitrate (PBN), Nitrogen oxides, aldehydes, ethylene etc.

i) Solid wastes

j) Radioactive waste

k) Noise

Types of pollution

On the basis of the type of environment being polluted, we may call air pollution, water pollution, soil pollution, marine pollution etc. And on the basis of the kind of pollutant involved, we may call SO_2 pollution, Fluoride pollution, CO-pollution, smoke pollution, lead pollution, noise pollution, radioactive pollution, solid waste pollution. Hence due to variety of pollutants, there are two basic types of pollutants :- viz Non-degradable and Biodegradable.

Non-degradable pollutants : Such materials and poisonous substances like aluminium cans, mercuric salts, long chain phenolics, DDT etc. do not degrade and if degrade but only very slowly in the nature. These are not cycled in ecosystem naturally. Such pollutants are not only accumulated but often biologically magnified with their subsequent movement in food chains and biogeochemical cycles also.

Biodegradable pollutants : Such pollutants are the domestic wastes which degrade easily in the nature. These create problems only when these are accumulated i.e. the accumulation of wastes into the environment exceeds its decomposition.

Air Pollution

Air pollution is the resultant of the direct or indirect change in the physical, chemical or biological characteristics of atmosphere which mainly results from gaseous emissions from industry, thermal power stations, automobiles, domestic combustions etc.

Sources of air pollutants

The main air pollutants are grouped into two major heads viz. natural and man-made.

[A] Natural source : such pollutants are created by the activities of the nature. The natural activities affect only limited area.

These natural sources are :

i) Volcano which emits gases, soots, smoke, particulate matters ets.

ii) forests fires

iii) Cyclones, typhoon, thunderstorms

iv) Fog

v) Decomposition of dead matters, vegetation, animals etc.

[B] Man-made Sources : include industry, thermal power stations, automobiles, farming practices, domestic use equipments, nuclear weapons and tests etc.

Petroleurn refineries are the chief source of gaseous pollutants like SO_2 and NO_x. [NO_x means NO, NO_2 etc]. Mathura based petroleum refinery has posed a great threat to Taj Mahal in Agra and other monuments at Fatehpur Sikri complex. Cement factories emit plenty of dust. Stone crushers and hot mix plants create more that is five times of SPM levels than the industrial safety limits. (SPM means suspended particulate matters). Food and fertilizer, chemical manufacturing industries emit gaseous pollutants.

The coal consumption of thermal plants is several million tonnes. The chief pollutants are fly ash, SO_2 and other gases and hydrocarbons. The three thermal power stations at the Indraprastha estate, Rajghat and Badarpur in Delhi are the main source of air pollution.

The ever increasing vehicles has been posing continued threat to the ambient air quality. In all the major cities of the country about 800 to 1000 tonnes of pollutants are being emitted into the air daily, of which 50% come from automobile exhausts. In the major metropolitan cities, automobile exhausts accounts for 70% of all CO, 50% of all hydrocarbons, 30-40% of all oxides and 30% of all SPM. The two-wheelers and three wheelers contribute 60% of the total CO and 83% of total hydrocarbons, whereas heavy traffic automobiles 55 to 80% of the oxides of nitrogen. It is estimated that a car (without cleaning device) on burning 1000 litre of fuel emits 350kg CO, 0.6kg SO_2, 0.1 kg lead and 1.5 kg SPM. The main sources of emission in automobiles are :-

i) exhaust system

ii) fuel tank & carburator

iii) Crankcase

Carbon compound pollutants

CO_2 : The main source of CO_2 pollutant in the atmosphere is the burning of fossil fuel (coal, oil etc.) either for domestic use (cooking, heating etc.) or for industrial use. The fossil fuel alone releases more than 18 x 10^{12} tonnes of CO_2 into atmosphere each year. And thermal power plants release around 50 million tonnes of CO_2 each year in India. The Indian coal also augments the situation because it has poor burning quality and has higher ash content i.e. 20-30% upto 45%.

The increase in CO_2 concentration in the atmosphere results into disastrous effect like greenhouse effect, but to some extent it increases the photosynthetic rate and consequently plant growth, acting as a fertilizer especially in hot tropical climates. This fertilizer potential of CO_2 may be achieved by enhancing the CO_2 content of the controlled atmosphere of plant / crop to get maximum photosynthesis and this process is known as **CO_2-fertilization or CO_2-enrichment**.

Greenhouse Effect : The increase in CO_2-concentration in the atmosphere makes its thick layer which is transparent to incoming solar radiation but opaque to outgoing terrestrial radiation. This thick layer of CO_2 functions like the glass panels of greenhouse or glasshouse (i.e. like the glass window of a car) which allow the incoming solar radiation to filter through in but prevent the heat from reradiated out in the outer space. This effect is known as greenhouse effect. 100 years back the CO_2 level was 275 ppm but today it is 350 ppm and by the year 2035 it would be 450 ppm. CO_2 increases the earth temperature by 50% while CFCs (Chloro fluoro carbons) are responsible for another 20% rise. The other gases like SO_2, NO_x, CFCs also contribute to green house effect.

The greenhouse effect of atmospheric CO_2 probably helped to create the necessary conditions for the evolution of life and the greening of the earth. The excess CO_2 to some extent is absorbed by the oceans but due to industrialization and our modernisation

increases the energy consumption which ultimately releases the CO_2 at a faster rate than the capacity of the ocean to absorb it. A rise of five degrees in the atmospheric temperature would raise the sea level by five metres within a few decades threatening all the coastal cities from Shanghai to San Francisco. According to US scientist George Woodwell, the mosoon rain of India may even cease altogether. Due to greenhouse effect there would be more hurricanes, typhoons and cyclones and early melting of mountain snow would cause more floods.

CO : The automobiles are the main source of carbon monooxide but stoves, furnaces, open fires, forest & bush fires, burning coal mines, factories, power plants etc are also the source. In atmosphere its concentration is upto 0.5 ppm. The level of CO in the urban areas is 5 to 50 ppm. Natural sources of CO are various plants and animals. The higher animal produces some CO from the breakdown of haemoglobin. Some CO is also liberated from bile juice. The breakdown of photosynthetic pigments in algae also releases some of CO. Plants on an average produce 10^8 tonnes of CO every year. CO is very harmful to those who are exposed to congested highways to a level of about 100 ppm. Hence the driver is the most affected person. It combines with haemoglobin of blood reducing its O_2-carrying capacity. More than 1000ppm of CO causes unconsciousness in an hour and death in four hours. The inhaled CO combines with haemoglobin and forms carboxyhaemoglobin about 210 times faster than O_2 does. the formation of **carboxyhaemoglobin** decreases the overall O_2-carrying capacity of blood to different cells resulting into oxygen deficiency known as **hypoxia**. The only higher levels i.e. 100 to 10,000 ppm of CO gas causes the leaf drop, leaf curling, reduction in leaf size, premature aging etc. It inhibits cellular respiration of the plant.

Sulphur compounds pollutants

SO_2 : The burning of fossil fuels (coal) in thermal power plants, smelting industries (smelting sulphure containing metal ores) and other processes such as manufacturing of H_2SO_4 and fertilizers are the major source of SO_2. These account for about 75% of the total SO_2 emission. Most of the rest 25% emission is from petroleum refineries and automobiles. It causes intense

irritation to eyes and respiratory tract. The moist air and fog increases the SO_2 dangers due to formation of H_2SO_4 and sulphate ions because H_2SO_4 is a strong irritant i.e. 4-20 times than of SO_2.

The plant is relatively more sensitive to SO_2 than the animal. It causes necrosis of leaf by bleaching of leaf pigments due to conversion of Chl-a to phaeophytin-a. The high concentration of SO_2 reduces the pH of leaf tissues and increases the total 'S' content of leaves and bark which ultimately increases the 'S' content of soil near the thermal power plant. Near the Indraprastha power station, Delhi, it is observed that there was a considerable reduction in the leaf area, leaf biomass and total plant biomass of *Dolichos lablab, Cicer arietinum, Lens culinaris, Phaseolus aureus* & *Vigna sinensis*. The indicator plant of SO_2 pollution is *Nerium indicum* in Delhi.

SO_2 also erodes the building materials such as limestone, marble, slate, mortar and statues.

H_2S : The decaying vegetation and animal matters especially in aquatic conditions releases H_2S. The other sources are sulphur springs, volcanic eruptions, coal pits and sewers. About 30 million tonnes H_2S are released by the ocean every year and 60-80 million tonnes per year by the land. About 3 million tonnes of H_2S are released every year by the industry. Even at low concentration it causes headache, nausea, collapse, coma and final death.

Nitrogen Oxides (NO_x)

In nature nitric oxide (NO) is produced by combustion of N_2 with O_2 during lightning discharges and by bacterial oxidation of NH_3 in soil. NO after combining with O_2 or O_3 forms more poisonous nitrogen oxide (NO_2) and NO_2 after reacting with water vapour in air forms HNO_3. The combustion of fossil fuel also contributes nitrogen oxides. About 95% of the nitrogen oxides is emitted as NO and only 5% as NO_2. In the urban areas about 46% of nitrogen oxides of air come from automobiles and 25% from electric generations. In the metropolitan cities like Delhi, Kolkata, Chennai & Mumbai, its main source is automobiles. NO_2 is a deep reddish brown gas. It is widely prevalent pollutant and is the main constituent of photochemical smog in the

metropolitan cities. NO_2 causes irritation of alveoli (lung), leading to symptoms resembling emphysema (inflammation) upon prolonged exposure to one ppm.

Photochemical smog : The term 'smog' was coined by H.A. Des Voeux in 1905 by combining two words viz smoke and fog.

Smoke + F**og** = Smog

The photochemical smog is such mixture of smokes and fog which is produced as a result of photochemical reactions among nitrogen oxides, hydrocarbons and oxygen. This smog consists mainly of O_3, NO_x, H_2O_2, organic peroxides, PAN (Peroxyacetyl Nitrate) & PB_ZN (Peroxy benzoil nitrate). In 1940s, the smog of Los Angeles, USA was produced due to an oxidising mixture of NO and hydrocarbons emitted from fumes i.e. domestic fires (50%) and exhaust of automobiles (50%) in presence of UV-radiation of sunlight. The photochemical smog is formed only during night or cloudy days. In 1987 a heavy smog was formed for about ten days in Mumbai. The serious outbreak of smog was occurred in Tokyo, New York, Rome and Sydney in 1970 which had spread asthma and bronchitis in epidemic form. The disease **Tokyo-Yokohama Asthma** was occurred in 1946 in some American soldiers & families due to living in smogy atmosphere of Yokohama of Japan. A disease '**emphysema**' is caused due to structural breakdown of alveoli of lungs by smog.

Some sulphates and nitrates may also be formed which are harmful to animals and plants and cause corrosion of metals, stones, building materials, monuments etc. The smoke and particulate matters of smog reduce the visibility and thus affect the day to day life.

Acid rain : The oxides of sulphure and nitrogen in the atmosphere are more likely changed into sulphuric acids and nitric acids. These sulphuric acids (H_2SO_4) and nitric acids (HNO_3) are then dissolved in water and fall to the ground as acid rain or may remain in clouds and fogs. The acid rain is infact a cocktail of the above acids and their ratio may vary according to the relative quantities of the oxides of sulphur and nitrogen pollutants. On an average H_2SO_4 accounts for 60-70% of the acidity and

HNO_3 for 30-40%. Industrialisation has increased the problem of acid rain. About 60-70% of the total SO_2 emitted globally comes from the burning of fossil fuels for power generation. Annually 20-90 million tonnes of NO_x are released from anthropogenic (human activities) sources over the globe. The oxides of sulphur and nitrogen can travel thousands of kilometers after sweeping up into the atmosphere and thus poses the ecological problem of acid rains globally i.e. The acid rain is carried away by prevailing winds to elsewhere where precipitation takes place. Canada gets acid rains from petrochemical units in North America. The heavy winds take up acid rain from factories in Britain & France to Sweden. The 90% of the acid rain of Norway and 75% of Sweden are due to drifted acid rains. In 1974, the pH value of acid rains over Scotland was found to be more sour than vinegar i.e. 2.4. Much of falling snow in Britain is now highly acidic and in the near future it will become a **pollution time bomb**.

In India, the pH value of rain water below or close to the critical value have been recorded in Delhi, Nagpur, Pune, Mumbai & Kolkata. It is only due to SO_2 from coal-based power plants & petroleum refinery. According to the study made by BARC, the average pH of acid rain was at Kolkata is 5.80, Hyderabad 5.73, Chennai 5.85, Delhi 6.21 and Mumbai 4.80.

The acid rain creates complex problems like- (i) it increases the soil acidity which affects the land flora & fauna (ii) it causes the acidification of lakes, ponds and streams (rivers etc.) which affects aquatic life, (iii) it affects crop productivity. (iv) it causes errosion of monuments, buildings, statues, bridges, fences etc. British Parliament buildings suffered damage due to H_2SO_4 rains. (v) And ultimately it poses a serious threat to human health.

In sweden more than 10,000 lakes have become acidic and so the case with thousands of lakes in U.S.A., Canada & Norway. Acidification of lakes drasticaly reduced the fish population causing the death of Salman trout etc. The fishless lakes (area) are now called **Fish graveyards**. The acidification also kills the most of the bacteria & blue green algae. In West Germany nearly 8% forests are died and nearly 18 million acres of forests are critically affected by acid rains. The acid rains also damaged the

forests of Switzerland, Netherlands & Czechoslovakia. Thus acid rains have been causing the disturbance in the ecological balance. Therefore, it is the urgent need for proper monitoring of and to combat the problem of the acid rain.

Ozone (O_3)

It is known to us that the ozone layer in the stratosphere (2nd layer of atmosphere) protects us from the harmful UV-rays of the sun. The ozone layer absorbs the ultra-violet (UV)-radiations coming from the sun and thus heats up the stratosphere causing the temperature inversion. Temperature in the troposphere (i.e. the lowest layer of atmosphere) decreases with the increasing height @ 1°C for 165m. metre (m) on height and it is known as **normal lapse rate of temperature**. But temperature ceases to fall and remains constant above tropopause (the junction of troposphere and stratosphere) upto a height of 20 km. Afterwards it gradually increases upto the height of 50 km (i.e. upto the beginning of mesophere i.e. 3rd layer of atmosphere) only due to ozone layer. This is called **temperature inversion**. The ozone layer filters out all radiations below 3000A°. The ozone layer limits the vertical mixing of pollutants over the larger areas and near the earth's surface. That is why the dense cloud of pollutants usually hangs over in the troposphere in the highly industrialised areas causing severe harmful effects. These pollutants spread horizontally relatively faster than of vertical mixing and reach all longitudes of the world in about a weak and all latitudes within months. Therefore it is not possible to protect the ozone layer by the efforts made by the single country.

Inspite of slow vertical mixing, some pollutants enter into the stratosphere and remain there for the long time. Therefore, stratosphere is considered as sink for some pollutant (CFCs) where they react with the ozone and deplete the ozone layer. The major pollutants responsible for this depletion are chloroflurocarbons (CFCs), nitrogen oxides (coming from fertilizers) and hydrocarbons. CFCs are in use as coolants in air conditioners, refrigerators, solvent cleaners, aerosol propellants, foam insulation and also in fire extinguishing equipment. Jet engines, motor vehicles, nitrogen fertilizers and other industrial activities are the sources of CFCs, NO_x etc. The supersonic aircrafts flying in

stratosphere cause major disturbance in the ozone layer. The CFCs deplete the O_3 by 14% at the current emission rate and NO_x by 3.5%. Thinning of the O_3-layer or the holes in the O_3 layer (i.e. **ozone hole**) causes cancer especially skin cancer (Melanoma). A 10% decrease in the O_3-layer of stratosphere leads to 20-30% increase in skin cancer. Near 6000 people die each year in USA due to such cancer. The thinning of O_3-layer also causes another disorders like cataracts, destruction of aquatic life and vegetation and loss of immunity. The 1% reduction in the O_3 of stratosphere increases UV-radiation by 2%. The plants exposed to UV-radiations showed a reduction of 20-50% in chlorophyll content and increase in harmful mutations under greenhouse effect conditions. The enhanced UV-rays also reduce fish productivity.

But near the earth's surface, the increase in O_3 concentration reduces the crop yields significantly. The O_3 enters into the plant through stomata and damages the leaves causing the decrease in yield and quality. At 0.02 ppm it damages tobacco, tomato, bean, pine & other plants. In pine seedlings it causes tip burn. In california (USA), the O_3 pollution (i.e. the increase in O_3-concentration) reduced the fruits and vegetable yields. In Denmark and Netherland the O_3 pollution affects potato, clover, beans, spinach, alfalafa etc. Rubber becomes hard after reacting with ozone. Many fibres like cotton, nylon, polyester and dyes also reacts with ozone.Thus while the higher level of O_3 in the stratosphere protects us but its higher level on the earth's surface is harmful.

The various global negotiations have been undertaken to protect ozone layer. In 1987, a convention for protection of ozone layer was recommended by UNEP governing council. Although it was 1985 in Vienna (Austria), where a convention was opened for signature to protect ozone layer. But this convention come into force from 22nd September 1988. Till June, 2001 this convention was ratified by 178 countries. Vienna convention was followed by Montreal Protocol (Canada) on 16th Sept. 1987. Many countries including India did not sign the protocol because India did not see any rationale as its release of CFC was just 6000 tonnes a year equivalent to one and a half day's of World's total. In India, per capita consumption of CFC is 0.02 kg. against 1 kg

of developed world. The three day international 'saving the ozone layer' conference was organised jointly in London in March 1989 by the British Government and the UNEP. There was another conference on ozone at Helsinki in May 1989 to revise the Montreal Protocol. India signed the protocol in Sept. 1992. The 18th Meeting of the Parties (MOP) to the Montreal Protocol on substances that deplete the ozone layer took place in New Delhi from 30th October to 3rd November, 2006, where issues of controlled use of methyl bromide, the difficulties faced by developing countries in transiting to CFC-free inhalers, cases of non-compliance and future challenges were discussed.

Fluorocarbons : A minute quantity of fluorocarbons prevents the tooth-decay in human but its higher level becomes toxic and creates a problem of fluorosis. The sources of fluorides in the atmosphere are industrial processes of phosphate fertilisers, ceramics, aluminium, fluorinated hydrocarbons (refrigerants, aerosol propellants etc.), fluorinated plastic, uranium and other metals. But fluoride pollution in man and animals is mainly through water. Fluoride causes tip burn in conifers due to accumulation in leaves because it enters into leaves through stomata.

Hydrocarbons : The main air pollutants are benzene, benzpyrene and methane and its main source is the motor vehicles. In our country two and three wheelers are the main contributors and in Delhi & Bangalore it accounts for about 65% of the total hydrocarbons. About 40% of the hydrocarbons emitted from vehicles are unburnt and the rest are the product of combustion. Benzene is a liquid pollutant emitted from gasoline. Benzpyrene is present in smoke, tobacco charcoal boiled stakes and gasoline, exhaust. Both Benzene and Benzpyrene are cancer -inducing pollutants. Methane (Marsh gas) is a gaseous pollutant which is produced in nature during the decay of garbage, aquatic vegetation etc. It is released from burning of natural gas and factories. When methane is released from the excess of water seepage area in excess quantity, it bursts with high sound.

Hydrocarbons combine with NO_x under UV-radiations of light and form other pollutants which are called photochemical products like PAN, PBzN, Olefins, Ozone, Aldehydes etc. Among

the above products, the aeromatics i.e. benzpyrene, PAN, PBzN are the most harmful pollutants. PAN is a potent *eye* irritant. PAN blocks the hill reactions in the plants and is injurious to spinach, beets, celery, potato, pepper, lettuce, alfalfa, etc. It also causes the silvering of the underside of leaves. Olefins are produced directly from automobile exhaust and from ethelene in the air. It withers the sepals of orchid flower, retards the opening of carnation flowers and causes the dropping of their petals. At high levels it retards the growth of tomato. Aldehyde causes irritation of eyes, skin and respiratory tract.

Metals

Common metals like mercury, lead, zinc and cadmium are released from industries and human activities in the air Mercury is a liquid volatile metal and is used in the production of fungicides, paints, cosmetics, paper pulp etc. The mercury toxicity causes headache, fatigue, anxiety, loss of apetite etc. and damages the nervous system, liver, eyes etc. Lead compounds are added to gasoline to reduce knocking which are emitted from the automobile exhaust as volatile lead halides. These compounds damages RBCs (Red Blood Corpuscles) resulting in anaemia and infections of liver and kidney. Zinc is released from steel, copper and lead refineries and open hearth furnace emits 20-25g Zn/hr in refining the galvanised iron scrap. In air it occurs mostly as white zinc oxide fumes which is toxic to man. The main sources of cadmium are the industries engaged in extraction, refining, electroplating, and welding of Cd-containing materials. Cadmium is also emitted from the production of some pesticides and phosphatic fertilizers. It is accumulated in human liver and kidney and causes hypertension, emphysema, and cancer even at very low level.

Particulate matters

The discrete mass of any material (except pure water) which exists in the atmosphere as liquid or solid and of microscopic or submicroscopic dimensions is known as particulate matter (PM). The PM arises from natural and man-made sources. Natural sources of PM are soil, rock debris (dust), volcanic emission, sea spray, forest fires and reactions between natural gas emissions. The natural biological particulate matter are bacterial cells, spores,

fungal spores, pollen grains etc. which sometimes causes bronchial disorders, allergy and other various diseases (like amoebiasis etc) in animals & plants. The main sources of PM are (a) fuel combustion & industrial operation (mining, smelting, polishing, furnaces & textiles, pesticides, fertilizers & chemical production) (b) industrial fugitive processes (like materials handling, loading & transfer operations) (c) Non-industrial fugitive processes (like roadway dust, agricultural operations, construction, fire etc.) (d) Transportation sources (vehicles exhaust & related particles from fire, clutch & break wear). In India, much of flyash is introduced in the air from fossil fuel based plants like thermal power plants. Stone-crusher introduces much of smoke & dust in the air. The dust and fumes of Badarpur plant (Delhi) are the curse for residents of Molad Band Village. Each 500-tonnes stones crusher emits 3 tonnes of suspended particulate matter (SPM) daily. The common disease **Byssinosis** of India is caused by the cotton dust.

Aerosols (Black clouds)

The particles about a millionth of a centimeter in diameter, consisting of sulphates, soot, organic carbon and mineral dust are called aerosols.

Table : Composition of a typical aerosol

S.No.	Components	Percentage
1.	Sulphate	32
2.	Organics	26
3.	Black carbon	14
4.	Mineral dust	10
5.	Ammonium	8
6.	Fly ash	5
7.	Potassium	2
8.	Minor inorganics	2
9.	Sea-salt + nitrate	1

The black clouds of aerosols are infact the thick layer of pollutants which affect seriously on rainfall and the onset of

monsoon through its effect on cloud formation. The availability of too much particulates in the atmosphere provides more nucleus for the condensation of water vapour and thus heavy cloud formation takes place. Such droplets hardly become big enough in size to fall as rain or snow. Water does not return to the fresh water stores and remains blocked as cloud in the atmosphere. In this way such aerosols affect the fresh water bodies as lakes, groundwater supplies, glacier etc. The black carbon aerosols have warming effect whereas sulphate aerosols have cooling effect. The cooling effect of sulphate aerosols balances the warming effects of black carbon aerosols. The warming or cooling effect is determined by the proportion of light scattered by aerosols. The aerosols reduce the heating of earth surface because they decrease the amount of solar radiations reaching the earth surface either by absorbing or scattering.

In highly polluted areas, clouds do not precipitate due to very tiny size of droplets whereas the clouds precipitate in less polluted areas within a short time of their formation. This aerosols increase the rainfall in southern India whereas winter rainfall is decreased in some parts of north-west India, Pakistan and Afganistan. The areas over the western equatorial pacific are also getting dry. These particulates start to influence on arrival of monsoon and its distribution in India. The aerosols reduce the photosynthesis and further reduce the amount of sunlight available to plants because of setting of aerosols. Such deposition of aerosols may change into acids.

The Nothern industrialised countries adversely affect the developing countries. The study made by scientists in Australia revealed that the sulphate aerosols formed by oxidation of SO_2 emissions from industries in North America & Europe might have been responsible for severe droughts in the Sahel region of Africa during the 1980s. The Rainfall in this region has fallen to 20-50% during the last 30 years. These emissions might have also caused greater rainfall in Australia due to shift of tropical belt southwards. Similarly transcontinental dust clouds originating from Asia and Africa (i.e. Sahara desert, Indus valley, Talimakan desert north of Himalayas, Gobi desert of Mangolia) are the most significant for North America.

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Prevention and control of Air Pollution

The steps must be taken to control pollution at source (i.e. prevention) as well as after the release of pollutants in the atmosphere. The engineer must consider the possibility of controlling of emissions by changing the process. To check the release of high levels of lead in the air, the simple solution is to eliminate the lead in the gasoline. The supply of unleaded petrol is the right approach in this regard. Thus the source have been corrected, the problem is solved. Similarly the alternative of such pollutants must be find out. Here the use of CNG (Compressed Natural Gas) is the right choice like in Delhi. Such measures like process change, conversion of raw materials or modification in the equipments to meet the standard emission (i.e. no pollution) are called controls. Whereas the term 'abatement' is used for all devices & methods for decreasing the quantity of pollutants reaching to the atmosphere, once the pollutants have already been emitted from the source.

To check the emission of pollutants from the automobiles, the following measures may be adopted:-

a) to use the new proportion of gasoline & air.
b) to use gas additives to improve combustion
c) to inject air into the exhaust to convert exhaust compounds to less toxic materials.
d) to update the engine design and / or to install abatement device to improve combustion with the existing engine design. I. K. Bharti of Mumbai claimed for such abatement device named 'Thermoreactor' to curb air pollution by motor vehicle. This thermoreactor is fitted to the exhaust tailpipe which converts carbon monoxide (CO) into pure oxygen.
e) Afforestation : to plant such plants which absorb carbon monoxide (CO) and nitrogen oxides (NO_x) from the air viz., *Daucus carota, Ficus variegata, Phaseolus vulgaris* are CO-absorbing plants whereas Pinus, Juniperus etc. absorbs nitrogen oxides.

Carbon monoxide is released from low air content of the fuel mixture whereas the production of NO_x is promoted by high

combustion temperature. Hydrocarbons follow the less or more pattern of CO. The complete elimination of CO, NO_x and Hydrocarbons may be achieved by the updating of the present engine design or by making adequate changes in devices for improving combustion.

To check the pollutants emitted from the industry, these following measures are to be adopted:

a) For the removal of the particulate matters, the appropriate equipments like cyclone collectors & electrostatic precipitators (ESPs) are used. In the cyclone collectors, the waste gas is subjected to centrifugation which removes about 70% of the particles. But in the electrostatic preci pitators. the electric forces are applied to the waste gas stream within the chamber in the precipitator where suspended particles become charged or ionised and such particles are attracted to the charged electrodes. ESP may remove 99% of the pollutant particles from the Chimney exhaust.

b) For the removal of gaseous pollutants, three methods viz. wet systems (having circulating alkali fluid continuously) where SO_2 is precipitated out), Dry systems (having Dolomite, lime, limestone where water & SO_2 forms H_2SO_4), and wet dry system (It is an alternative to traditional wet system where absorbent $Ca(OH)_2$ slurry is spread into the hot gas steam and calcium reacts with SO_2 and hot gases causes the water to evaporate. And end product is dry powder of mostly flyash & salts. Other absorbent like charcoal etc may be used. Combustion of gases is used in the petroleum refineries).

c) Standards are to be enforced through the appropriate Acts & Rules.

Noise Pollution

The word noise is derived by the Latin word nausea meaning unpleasant sound which causes discomfort. Noise may be defined as the wrong sound in the wrong place at the wrong time. Thus the noise is itself pollution which means the unpleasant sound produced in the atmosphere leading to discomfort or the health hazards.

decibel & Hertz:- There are two basic properties of sound viz., loudness and frequency.

Loudness is the strength of sensation of sound percieved by the individual. It is measured in terms of decibel (i.e. dB). Loudness is also expressed in **sones**. One sone is equal to the loudness of 40 dB sound pressure at 1000 Hz. Just audible sound is about 10dB. Mumbai, New Delhi, Kolkata & Chennai usually have more than 90dB.

Frequency of sound is defined as the number of vibrations per second. It is denoted as Hertz(Hz). One hertz is equal to one vibration per second. We hear the sound between 16Hz (i.e. infra-audible) to 20,000 Hz (ultrasonic sound).

Sources of Noise

The main sources of noise are factories & industries, transportation (air, road, rail and ship) and community and religious and cultural activities. The main man-made sources in the urban area are automobile, factories, industries, train, aeroplanes. As far as our country is concerned, we are noisy people and every sentiment either religious, social, cultural or family activity is celebrated in a noisy way. Loudspeakers and amplifiers are used at every occasion. God and Allah is listened only through loudspeakers. Now a days 'Jagrans' become a regular feature in the name of devis and has been spreading like a plague. The procession is become must for dancing and drinking on the occasion of marriage and also on election.

Effects of Noise Pollution

Noise is harmful to the body and mind. It causes irritation or annoyance, headache, constricts the arteries, increases the flow of adrenaline and forces the heart to work faster. Continuous noise increases the cholesterol level resulting in the constriction of blood vessels which leads to heart attack and strokes. The noise causes a number of physiological disorders due to imbalance in functioning of the body e.g. neurosis, anxiety, insomnia, hypertension, hepatic diseases, behavioural & emotional stress, increase in sweating, nausea, fatigue undesirable changes in respiration, peptic ulcer. It reduces depth and quality of sleep thus affecting overall mental and physical health. Noise creates

the disturbance in doing mental work and causes ill-temperament. A noise of 50-60 dB generally interferes with speech. Even a low level of noise from crowd, highway, TV, radio etc. causes the great annoyance for the balanced persons. The auditory fatigue occurs at the 90 dB with side effects as whisling and buzzing in ears whereas at 100dB, permanent loss of hearing occurs. Mumbai & Kolkata are the noisest cities in the world. Supersonic aeroplane creates a shock wave called **sonic boon** which produces a startle effect. That is more harmful than continuous noise. It may damage the window pans and building structures. It increases the heart beat rate of human foetus.

Table : Noise intensity and health hazards

Noise intensity (in dB)	Health hazards
80	Annoyance
90	Hearing damage
95	very annoying
110	stimulation of reception in skin
120	Pain threshold
130-135	Nausea, vomiting, dizziness
140	Pain in ear
150	Burning of skin
160	Rupture of tymphanic membrane
180	Major permanent damage in short time

Table : The noise intensity from different sources

Intensity (dB)	Source
10	Breathing
20	Broadcasting studio
20-30	Soft whisper
30	Trickling clock
30-35	Library
35-40	Low volume radio
35-60	Normal conversation

60	Telephone
60-80	Office noise
70-80	Alarm clock
50-90	Traffic
90	Trunk
105	Motor cycle
105-110	Lion's roar (12')
100-110	Jetfly (over 1000')
110	Train whistle (50')
110-120	Air craft (100') (prokeller driven)
110-120	Pneumatic drill
120-140	Commercial jet (Air craft (100')
120	Jet take off (300')
70-180	Space rocket (launching)

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Control of Noise pollution

The followings are the ways to control and reduce the noise:-

a) **Control at source :** This may be achieved by (i) designing and fabricating silencing devices in air-craft engines, automobiles industrial machines and home appliances, (ii) by seggregating the noisy machines.

b) **Control at transmission levels** : It may be achieved by covering the room walls with sound absorbers as acoustic tiles and by constructing the enclosures around industrial machinery.

c) **To protect exposed individual :** The wearing devices like ear plugs & ear muffs should be used by the individual going to the noisy areas.

d) **Afforestation and reforestations :** The sound energy is absorbed and is dissipated by the plant canopy and the series of plants act as buffer zone. Thus the plants of the large canopy like Ashok, Neem, Peepal, Tamarind etc should be planted along the highways, streets and other areas.

e) **by making law :** In India, motor vehicle Act provides restriction on trucks using double sirens while passing through some localities. The indiscriminate use of loudspeakers and amplifiers should be banned at the public places by making the law. Silence zone must be created near schools, hospitals and residential areas. Fortunately noise has now been included under Air pollution in the Air pollution control Act. The Central Pollution Control Board (CPCB) has set following standards for the noise level in certain ambient atmosphere.

Table : Areas having set standard of noise level

S.No.	Area Code	Category of Area/Zone	Limit in dB(A) Leq*	
			Day time	Night Time
1	(A)	Industrial area	75	70
2	(B)	Commercial area	65	55
3	(C)	Residential area	55	45
4	(D)	Silence zone	50	40

Note:

1) Day time is reckoned in between 6 a.m. & 9 p.m.
2) Night time is reckoned in between 9 p.m. & 6.a.m.
3) Silence zone is defined as areas upto 100 metres around such premises as hospitals, educational institutions & courts. The silence zones are to be declared by the competent authority. Use of vehicular horns, loudspeakers and bursting of crackers shall be banned in these zones.
4) Mixed categories of areas should be declared as one of the four above mentioned categories by the competent authority and the corresponding standards shall apply.

*dB(A) leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

A "decibel" is a unit in which noise is measured.

"A" in dB(A) leq denotes the frequency weighting in the measurement of noise and corresponds to frequency response characteristics of the human ear.

Leq : It is an energy mean of the noise level over a specific period.

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f) Education : Awareness about the noise nuisance must be created through the various means like news, media, lectures & other programmes. Majority of the people do not consider noise as a pollution. Therefore people must be educated about the effects of noise.

Water Pollution

Water is generally available in two forms on our earth viz. marine (saline) water and fresh water. Saline water constitutes about 97.5% of the total water present on the earth and is found in oceans or seas. Fresh water is utilised by man and constitutes only 2.5% of the total water. Out of 2.5% only 0.5% is available for human use.

Normally water is never pure in a chemical sense but it contains impurities of various kinds i.e. suspended as well as dissolved. Water is itself a purifying agent but the alternation in it's physical, chemical or biological characteristics which damages the water quality is called water pollution. There are numerous sources of water pollution but the major sources are :-

a) Sewage & other wastes
b) industrial effluents
c) agricultural discharges
d) industrial wastes from chemical industries, fossil fuel (thermal power) plants and nuclear power plants.

a) Sewage and other wastes

Sewage is the water borne waste whose sources are domestic wastes and animal or food processing plants. The self purifying ability of water is lost due to the decrease in decomposition of waterborne wastes by aerobic microbes which increases its BOD. The Biological Oxygen Demand (BOD) is a measure of the amount of oxygen required by microbes while stabilising decomposition. Chemical Oxygen Demand (COD) is the amount of oxygen required for chemical oxidation instead of biological. The value of BOD is therefore used as a measure for the degree of water pollution and the waste level. Thus the oxygen level is depleted with the addition of sewage and wastes and the BOD value of water is increased. The no. of microbes viz *Escherichia*

coli (bacterium) also increases tremendously which consume most of the oxygen. The no. of E.coli in unit volume of water may also be taken as a parameter of water pollution i.e. E.coli index. DO means dissolved oxygen which is the quantity of oxygen dissolved in water. Generally the fish can't survive at DO value of 4-5 ppm of water.

The most of the detergents & soaps contains phosphates and other nutrients. The addition of such rich nutrients especially phosphates & nitrates ions from the home wastes to the water bodies favour the luxurient growth of algae i.e. forms water blooms. Thus the water body becomes very productive or eutrophic and this phenomenon is known as **Eutrophication**. Eutrophication results into the decrease in O_2 level in water. Sometime decomposing plants produce a toxin called **strychnine** which kills fish and animals including cattle. These algal blooms compete with other aquatic plants for light for photosynthesis which results in the depletion of oxygen with higher CO_2 levels. The best examples of eutrophication is the lake Erie of USA, where in 1965, more than 80 tonnes of phosphates were added daily. Each 400g of phosphate causes the growth of about 350 tonnes of algal slime. The big mounds have appeared on the lake shore due to the algal growth causing the interfere with fishing and navigation, producing unpleasant smell clogging pipes. Thus eutrophication is the limiting factor in the clean water supply for drinking, fishing, navigation etc.

Sewage is the excellent medium of growth for pathogens. Several pathogenic microbes come from the wastes and spreads fatal water-borne diseases like viral hepatitis polio(viral), cholera, typhoid, dysentry, diarrhoea (bacterial), amoebiosis (protozoal) etc.

b) Industrial effluents

Industrial effluents are one of the most important agents of water pollution. Effluents may be inorganic, organic or both which contain toxic chemicals, heavy metallic wastes, hazardous compounds, suspended solids, non-biodegradable matters, radioactive wastes and thermal pollutants from various industries. These effluents may even poison the biological purification

mechanism of sewage treatment plant when discharged into the sewage system. Most of the effluents are insusceptible to degradation. The nature of effluents depends on the type of industry e.g. H_2SO_4 is an acid waste from coal mines which causes the hardness of water, corrodes concrete, diastrous effect on living organisms etc. About 180 million litres of toxic effluents are discharged into the Periyar river every day in the greater Cochin area. The Vembanad lake and Chitrapuzha estuarine water way receive about 78 million litres of effluents every day.

c) Agricultural discharges

In modern agricultural practices chemical fertilizers and pesticides (biocides) are heavily used. Some of these are washed off through rainfall, irrigation and drainage into water bodies, where they severely damage and disturb the aquatic ecosystem. Some pesticides can also pass into food chain and finally enter into human bodies.The chemical fertilizers and biocides disturb and damage the natural ecosystem of the top soil. The microbes (bacteria, fungi, worms etc.) are present in the top soil and enrich the humus but are badly affected by the chemical application.

Since the chemical fertilizer consists of only a few minerals, it hampers the uptake of other minerals and imbalances the whole mineral pattern of the plant body. Today, the excessive use of nitrogenous fertilizers cause the K-deficiency in plants and the excessive K-treatment decreases the valuable nutrients in foods like vit. C (ascorbic acid) and carotene. Liming prevents the release and uptake of Co, Ni, Mn and Zn. Application of superphosphate may cause the Cu and Zn-deficiency. Nitrate fertilizer increases the total crop yield (i.e. carbohydrate) but on the cost of protein. Findings showed that 20-25% decline in protein content in corn & wheat was observed when grown on soil fertilised with N.P, and K. Moreover it lowers the balance of amino acids lowering the protein quality.

The chemicals produce oversized fruits and vegetables but are prone to insect pest and diseases. When the nitrate of fertilizers is taken up by the human, this nitrate is converted to nitrites by the Flora of our intestine and these nitrites form **Methaemoglobin** after combining with haemoglobin of blood

and thus interferes with its O_2-carrying capacity. This disease is called **methaemoglobinaemia**. There is 0.8% of methaemoglobin in a healthy person but its higher percentage causes various problems and at 80% death occurs. Nitrate-poisoning is frequent in Rajasthan due to hard and saline water. In 1976, there were cases of nitrate-poisoning of cattle in Nagpur. The consumption of vegetables grown in nitrate rich soil may also cause this disease.

The hazardous biocide chemicals enter our food-chain and increase its concentration at each successive trophic levels (Bio-magnification) causing considerable harm.

(d) Industrial wastes (Physical pollutants)

There are two major pollutants viz. heat & radioactive substances among industrial wastes. The huge quantity of waste water from the thermal power plant is returned after use at very high temperatures to the streams (lake, river) which affects the aquatic life. This is called **thermal pollution** because heat acts as a pollutant. The waste water from nuclear power plant is not hot but still has adverse effects on aquatic life viz. early hatching of fish eggs, failure of trout eggs to hatch, failure of salmon to spawn, increase in BOD, significant shift in algal forms, the change in macrophytes, migration of some aquatic forms, change in diurnal and seasonal behaviour as well as metabolic responses of organisms.

Water Pollutants

The followings are the major water pollutants :-

i) Organic pollutants
ii) Inorganic pollutants
iii) Thermal Pollutants
iv) Sediment
v) Radioactive materials

i) Organic pollutants

Water carrying the organic pollutants has decreased level of dissolved oxygen (DO) because all these compounds can undergo bacterial degradation in the presence of oxygen. Such organic pollutants are oxygen demanding wastes, disease causing agents,

plant nutrients, sewage, and synthetic organic compounds. The main sources of such organic pollutants are excreta of an infected person, sewage system and agricultural runoff. The presence of synthetic organic compounds like fibres, detergents, paints, food additives in water add nasty taste, odour and colour to it.

ii) Inorganic pollutants

These are mainly inorganic salts, mineral acids, metallic compounds, trace elements, organometallic compound and it's main sources are industries. Many coal mines discharge substantial amounts of H_2SO_4 into groundwater through **seepage**. The organometallic compounds are highly toxic to aquatic life.

iii) Thermal pollutants

The major sources of these pollutants are coal power plants, nuclear power plant, sewage, and industrial processes.

iv) Sediment

Sediment in water usually comes from natural process of soil erosion. Sediment is washed away during rainfall and runoffs. The rate of soil erosion is increased by the human activities like deforestation, agricultural runoff, construction processes and mining activities. Sediment interferes in the natural processes of aquatic organisms by reducing light penetration in water bodies.

v) Radioactive materials

The major sources are nuclear weapons, nuclear power plants, mining of radioactive substances, medical research & industrial applications, These radioactive materials can enter the food chain in aquatic ecosystems and completely disrupt the metabolic pathways. Each year a large nuclear plant produces 5 tonnes of treated wastes. Radioactive wastes are put in stainless steel drums and stored deep underground. It is then surrounded by concrete and sealed. Low level radioactive wastes are put in drums and burried in shallow pits.

Effects of water pollution

1. The pathogens found in sewage are responsible for many diseases.
2. It makes water unfit for drinking and domestic use

3. Decrease in dissolved oxygen (DO) leads to production of foul odour in water.
4. The self purifying ability of water is lost.
5. Industrial effluents have deleterious effects on living organisms and may cause death.
6. Heated effluents discharged into water bodies may severely alter the aquatic system and life.
7. Industrial effluents impart colour, foul odour and turbidity to receiving water.
8. Thermal pollutants accelerate the activities of pathogenic organisms and thus give an impetus to their population.
9. Excessive sediment decreases the depth of rivers, streams, lakes etc and makes the water to overflow.
10. Sediment reduces the light penetration and lowers the photosynthetic activity of aquatic plants.
11. Radioactive wastes present in water causes cancer, eye cataract, DNA breakage and carcinoma in man.
12. Radioactive wastes destroy the biological immune system.

Marine Pollution

Marine pollution is defined as the discharge of undesirable substances in oceans or sea water causing changes in physical, chemical and biological characteristics of water which might prove harmful to marine organisms and affect the usage of oceans or sea water. All that are carried by rivers, are dropped into the sea. The discharge of oils and petroleum products and dumping of radionuclide wastes into the sea also cause marine pollution. Sewage contributes excessive of nutrients in sea water which lead to fast growth of algae and some other sea weeds, preventing the sunlight to reach in depth. The major sources of marine pollution are sewage, industrial effluents, synthetic detergents, pesticides, fertilizers, heavy metals, oils and petroleum products, radionuclide wastes, plastics.

The most serious pollutants is oil. A single drop of oil spreads over a large area of water. Oil layer may isolate water from coming in contact with atmospheric oxygen. The shortage of oxygen inhibits growth of plankton which forms the basis of the food chain in aquatic ecosystems. About 285 million gallons of

oil are spilled each year into ocean, mostly from transport oil tankers. About 50,000 to 2,50,000 birds are killed every year by oil. The oil is soaked in feathers and the air of feathers is displaced and thus it interferes with buoyancy and maintenance of body temperature. Hydrocarbons and benzpyrene accumulate in food chain and consumption of fish may cause cancer. On 18.03.1967, a liberian tanker Terry canyon spilled over 60,000 tonnes of crude oil into the entrance of the English channel of the Great Britain. This oil splattered over to 160km of coastline killing fish and birds. On 24.3.1989, the Supertanker Exxon Valdez spilled over 11 million gallons of oil into the clean water of Alska, USA where oil splattered over 1930 km of shoreline killing 100,000 seabirds. In 1973, the oil tanker, Cosmos Pioneer ran aground and 3000 tonnes of oil splattered to the Gujarat coast. In 1974, an American oil tanker, Transhuron collided with one of the atolls of the Laccadives spilling 5000 tonnes of special furnace oil. In June 1989, M.T. Puppy (Maltese tanker) collided with a British vessel spilling over 5500 tonnes of furnace oil into the open sea off Mumbai. The massive oil slick in the Gulf in 1991 has been the largest so far spreading over 700 sq. km.

The pollution in Baltic sea along the coast of Finland, has occurred largely from sewage and effluents from wood industries. The radionuclide wastes in sea include Sr-90, Cs-137, Pu-239, Pu-240. Many sea birds suffer from gastro-intestinal disorders due to the ingestion of plastic. A huge amount of plastic packing materials is being dumped into sea and many more are entered through rivers. The pollutants in sea are dispersed by turbulence and ocean currents and are concentred into the food chain.

Water pollution due to oil may lead to the following detrimental effects:

1) Oil layer reduces the rate of O_2-uptake significantly by water.
2) Oil coating does not allow the fish to respire and clog their gill slits.
3) Oil layer decreases the light intensity penetrating deep in the sea.
4) Natural insulating oils and waxes which shield the birds from water are destroyed by oil coating in sea water.

5) Several birds die because their fur and feathers become oil saturated and agglomerated.
6) Oil spill also affects the terrestrial food chain.

Mercury pollution

Mercury is one of the water pollutants. Both organic and inorganic forms of Hg are highly poisonous. Mercury was found responsible for the **Minamata** epidemic disease that caused several deaths in **Japan and Sweden**. This disease was occured due to consumption of heavily-contaminated fish. The source of Hg to the bay was a single chloride producing plant where $HgCl_2$ was used as a catalyst. In Sweden the widespread use of mercury compounds as fungicides and algicides in paper and pulp industries and in agriculture polluted the many rivers and lakes. The main source of Hg-containing effluents is chloral alkali plant. The paper & pulp industries also cause Hg-toxicity in Japan and Canada. The effluents from batteries, thermometers, fluorescent light tubes, high density street lamps and switches-making industries also contain Hg.

At the bottom of the water bodies, the mercury is metabolically converted into highly persistent methyl mercury compounds by anaerobic microbes. Methyl mercury is soluble in lipids and thus accumulated in fatty tissues of animals when eaten up. Methyl mercury ions may directly be accumulated in Fish. In Minamata bay all the mercury in sea-food was as organic methyl mercury compounds. Swedish fish eaters have also high Hg-content in their blood.

Lead Pollution

The main sources of lead to water are effluents of lead & lead processing industries. But Lead toys, paints, some plastic pipes, lead containing pesticides, food, beverages, ointments and medicinal concoctions for flavouring and sweetening also cause lead-pollution.

Cadmium- contaminated drinking water and its high level in rice causes the **Itai-itai (ouch-ouch)** disease.

Fluoride pollution

In nature fluorine is found as fluoride. In Haryana & Punjab,

consumption of fluoride-rich water from wells caused endemic fluorisis. High fluoride content water caused dental fluorisis in Andhra Pradesh and Rajasthan. Many people of Rajasthan have humped back only due to high fluoride content in water. Prolonged intake of fluoride causes stiffness in bone joints particularly of spinal cord. Fluoride has an affinity with Calcium and thus gets accumulated in bones, resulting in the mottling of teeth, pain in the bones and joints and outward bending of legs from the knees. This is known as **Knock-knee syndrome**.

Control of water pollution

The water pollutants may be either biodegradable or non-degradable or slow degradable. The biodegradable pollutants may be controlled at source by their treatment for reuse and recycling but the non-degradable or slow degradable pollutants may be removed by appropriate techniques. To control water pollution the various ways are :-

a) Stabilization of Ecosystem: The basic principles for stabilization of ecosystem are the reduction of waste-inputs (i.e. control at source), harvesting and removal of biomass, trapping of nutrients, fish management and aeration. Biological and physical methods can be used to restore ecological balance and biodiversity in the waterbodies.

b) Recycling and reutilisation of wastes: Different types of wastes viz. industrial effluents, sewage/sludge, thermal pollutants etc. may be recycled and reutilised e.g. The urban wastes may be recycled to generate electricity and fuel gas at cheaper rate. NEERI (National Environmental Engineering Research Institute), Nagpur developed a technology for the management of radioactive wastes and chemical wastes of atomic power plants, the reclamation of waste water and the supply of cheap piped gas. NEERI also generated the electricity from recycling of urban wastes.

c) Removal of pollutants : Different types of water pollutants may be removed by suitable techniques and methods viz., absorption, reverse-osmosis, electrodialysis, ionex change etc. Reverse-osmosis is commonly used to desalinate the brackish (saline) water and to purify sewage water. NH_3 may be removed

by ion-exchange process in the form of $(NH_4)_2SO_4$ which may be used as a fertilizer. Mercury may be removed by mercury selective ion-exchange resin. The phenolics may be removed by polymeric absorbent from the waste water of pulp and paper mills, carbonisation plants, petroleum refineries, tanneries, resin plants etc. The colour of waste water from printing and sari dying industries can be decolourised by an electrolyte decomposition technique. The Wall Street Journal of America claimed the use of solar power for cleaning up of polluted water at cheap rate.

d) Control through law and enforcement of standard-

To control air, water and noise pollution in India these are the following Acts:

1) The water (prevention and control of pollution) Act. 1974
2) The Air(Prevention and Control of Pollution) Act, 1981
3) The Environment (Protection) Act, 1986
4) The motor vehicles Act, 1988.

The central pollution control board (CPCB) has been constituted to make recommendations and advices on pollution matters to the central government. The CPCB established the Minimum National Standards (MINAS) and the air emission standards to control Pollution at source. These standards mean the maximum limit of effluents and emissions discharged into the water bodv or atmosphere.

The Govt. of India launched Yamuna Action Plan (YAP) in April,1993 with the following objectives:-

i) To build sewage treatment plants (STPs) to treat domestic sewage.
ii) To build common effluent treatment plants to treat industrial effluents
iii) To repair sewage system- drains, pumps, pipes.
iv) To build sewage systems and low cost toilets to connect the waste of slums and poor settlements to treatment plants and
v) To build electric crematoria.

So far, the scheme have been implemented in 21 towns along the river in the U.P., Haryana and Delhi.

The **Ganga Action Plan (GAP)** was launched in 1986 by the late Prime Minister Rajiv Gandhi to improve the water quality using a multi-pronged strategy. The National River Conservation Plan (NRCP) was launched in 1995 to improve the water quality (upto bathing class) of the rivers which are the major fresh water sources in India. So far it covered 34 rivers under the programmes with following objectives:-

i) Interception and diversion works to capture the raw sewage flowing into the river through open drains and divert them for treatment.

ii) Setting up sewage treatment plants for treating the diverted sewage.

iii) Construction of low cost sanitation toilets to prevent open defecation on river banks.

iv) Construction of electric crematoria and improved wood crematoria to conserve the use of wood & help in ensuring proper cremation of bodies brought to the burning ghats.

v) River front development works e.g. improvement of bathing ghats.

vi) Afforestation & public awareness & participation.

Generally three types of water pollutants of a river viz., silt, biological and chemical. Sedimentation may be reduced by rehabilitation of catchment area through tree plantation. Biological pollution has the three sources i.e. (i) urban liquid and solid wastes (ii) dead bodies of human and animals (iii) Wallowing of cattles and mass-bathing. The sources of chemical pollution are industries and domestic sources.

The National Lake Conservation Plan has been approved by the Govt. of India in May, 2001 with the objectives to restore and conserve polluted and degraded lakes and other similar bodies namely tanks/ponds etc. So far 37 lakes have been covered under this plan including Dal-lake of J & K and Velli Akkuluam in Kerala. The National Wetland Conservation Programme was initiated in 1987 with the basic following objectives:-

i) Assessment of wetland resources

ii) identification of wetlands of National importance,

iii) Promotion of Research and Development activities

iv) Formulation and implementation of management action.

Wetland is the such transition lands between the terrestrial and aquatic system where water table is usually or near the water surface and such land is covered by shallow water.

It means the area saturated by surface or ground water having life adopted under this conditions e.g. swamps, bogs, fens, marshes, estuaries, deltas etc.

Soil Pollution

Soil is actually the outer covering of the earth's crust. It is the soil on which we live on and get our food supply. Unsustainable Agriculture, Rapid industrialisation, urbanisation and population explosion have resulted in soil pollution.

The undesirable changes in physical, chemical and biological characteristics of soil, which are harmful for all living beings, are collectively known as soil pollution. Soil pollution is quite different from air pollution and water pollution as in soil pollution, pollutants remain in direct contact with soil for a relatively longer period.

Sources of soil pollution

There are various sources for soil pollution but the main sources are :-

[A] Man-made sources

a) Agricultural Practices

b) Disposal of solid wastes on land

c) Mining activities

d) Biological agents

e) Radioactive pollutants

f) Heavy metal pollutants

[B] Natural sources like volcanoes, tsunami waves, storms near desert areas etc.

[A] (a) Agricultural Practices

With the increased use of agro-technology, huge quantities of fertilizers and pesticides are applied to increase the yield of various crops. Irrigation with poor quality water and presence of pesticide residues and heavy metals from applied nutrients are

the major causes of soil pollution. The use of inorganic nutrients for a long time gradually declines the soil fertility. The unsustainable intensive cropping systems reduces the organic carbon content of soil. The fertilisers or chemicals when applied in the soil undergo various transformation and its runoff and erosion result in eutrophication of water bodies. Many fertilisers containing varying amounts of trace elements viz. arsenic, cadmium, chromium, mercury, nickel, lead etc may accumulate in soil and may cause long term effects on crops yields and quality and may damage soil microflora. Some toxic metals viz. cadmium, lead, nickel and mercury may be absorbed by the plants where they don't show any detrimental effects because of their deposition in vacuoles, cell walls and barks of plants. When such plants especially vegetables are eaten up, they may cause several health problems.

The intensive inappropriate tillage practices lowers the capability of soil. The various land-degradation problems whose major causes are deforestation, overgrazing, inappropriate cultivation without soil and water conservation, industrialisation, poor management of irrigation and rain water and other agricultural inputs; have affected almost 60% of the total geographical area. The practice of shifting cultivation exposes land to soil erosion. The agricultural wastes viz. plant and animal wastes, debris, farm wastes and crop residues are responsible for posing soil pollution problems and changing the natural composition and structure of the soil.

b) Disposal of solid wastes on land

The solid wastes pose a serious threat especially in developed effluent countries like USA and European countries. In India, several million tonnes of solid waste is dumped along highways and other places in big cities like Delhi, Mumbai, Chennai, Kolkata, Lucknow, Jaipur, Ahmedabad, Patna etc. On an average, over 2 million tonnes of solid wastes is generated in Class I cities per year whereas 0.25 million tonnes/year in class II cities. In western world used vehicles have been creating much problem.

The solid wastes are mostly generated from industrial, domestic and urban, and agricultural sources. The industrial wastes are mainly discharged from pulp and paper mills, chemical

industries, oil refineries, textiles, fertiliser & metal processing industries. The industrial wastes mainly include toxic pollutants, heavy metals, organic compounds, inorganic complexes, and non-biodegradable materials. The industrial pollutants which pollute air and water also pollute the soil.

The solid wastes generated in Indian cities mainly contain sludge, garbage, plastics, glass materials, metallic cans, fibres, waste paper, street sweepings, packing materials, fuel residues, leather, rubber, domestic and street refuse. Overpopulation and increasing consumption have totally changed the very complexion of urban wastes into a complex mixture of food remains, papers, paints, varnishes and many other toxic chemicals. Urban wastes are also dangerous like industrial wastes because some of these do not degrade easily. The agricultural wastes have already discussed earlier.

c) Mining activities

The top layer of soil is generally damaged or destroyed during both shaft and strip mining practices. Mining results in loss of fertile land, formation of huge mountains of wastes, and addition of harmful substances to the soil. The uncontrolled mine fires may also destroy the productivity of the areas near mines.

d) Biological agents

The major sources of biological agents causing soil pollution are human excreta, animal and bird excreta, municipal wastes, biomedical wastes and faulty sanitation. The industrial parasites are among the most threatening biological agents.

e) Radioactive pollutants

Huge amounts of radio-active substances result from nuclear device explosions, nuclear testing laboratories, nuclear power plants and weepons. All these are responsible for radioactive fall out, thus, further enhancing soil pollution.

f) Heavy metal pollutants

Heavy metals in soil are basically due to industrial discharges. Certain heavy metals e.g. Zn, Cu, Ni, Cd and Pb are also present in significant levels in sewage sludge and reach the soil where they become part of life-cycle and affect adversely.

[B] Natural sources : e.g. Tsunami waves on 26.12.04 caused heavy soil pollution near coastal areas of India, Sri Lanka, Singapore and Maldives.

Effect of Soil Pollution

1) Excessive use of fertilizers and pesticide chemicals does not allow microbial flora and fauna in soil to flourish.
2) Excessive use of nitrogen and phosphatic fertilizers makes the soil deficient in other micronutrients like Zn, Co etc and causes nutrition imbalances.
3) Soil fertility is reduced or adversely affected if pesticides remain in soil for longer period.
4) Pesticides like DDT, dieldrin etc. are known to seep gradually through soil into ground water and thus contaminate public drinking water supplies.
5) Farm animals can even die by drinking stagnant water in fields contaminated with pesticide.
6) People in contact with pesticides are extremely prone to get poisoned.
7) Some of the industrial wastes are extremely toxic for organisms.
8) The industrial as well as other wastes may be transferred to all organisms through food chains.
9) Pathogens found in sewage are infectious to men and animals.

10) Solid urban wastes and industrial wastes produce foul and offensive odour.
11) Construction materials and other garbage pile up at places and cause obstruction in day-to-day activities.
12) Stray animals further spread the heap of wastes.
13) Heavy metals and other toxic substances (impurities from mining activities) can destroy beneficial microorganisms of the soil.
14) Rate of retention and absorption of heavy metals is higher in infants and children.
15) When rain containing radionuclides falls on the soil, the radioactivity gets transferred to the soil due to its absorption by the soil particles.

16) Rain also adds radioactive contaminants into water bodies thus affecting the aquatic flora and fauna.
17) Radioactive pollutants can cause a number of undesirable disease of digestive system if they enter our body through food chain.

Control of soil pollution

1) Adoption of sustainable agriculture having organic farming and use of biofertilizers, biointegrated pest management and proper water management, composting etc.
2) Adoption of suitable and proper industrial and urban wastes management.
3) To educate the people about the wastes dropping at the proper place.
4) Use of proper sanitation.
5) Adequate controlled use of heavy metals and toxic substances.
6) Go for bioremediation of polluted soils. e.g. *Thiobacillus ferroxidans* is an iron and sulphur-oxidising bacterium. This bacterium brings about bioleaching of zinc, cobalt and nickel from sulphide rocks.
7) afforestation, social & agro-forestry,
8) Use of platic bags, containers and other plastic products should be discouraged.
9) Non-biodegradable wastes can be recycled and used again.
10) Biomedical wastes should be carefully disposed off so that it does not create any health hazard.
11) Use of incinerator which converts solid wastes into liquid and then into gaseous forms.

Nuclear Pollution / Radiation Pollution

Radioactive substance releases invisible radiations which cause many deleterious effects on all living organisms directly or indirectly. These radio-active substances are radium, uranium, plutonium, polonium etc. Low levels of ionising radiations have been emanating from natural resources since evolution but the level of exposure has increased enormously after the advent of nuclear weapons and the development of nuclear energy. Nuclear pollution is a kind of physical pollution of the environment and it differs from air, water, and soil pollution in the respect that it can bring about physiological changes in the present and future generations of all living beings. There is no safe dose of radiation.

Sources of nuclear pollution

[A] Natural sources

a) Solar and cosmic radiations

b) Internal radiation which is released during the decay of some elements within our body e.g. decay of K in our muscles releases radiations within our body.

c) Radiations from radio-active elements

[B] Anthropogenic sources

Such sources are related to human activities.

a) Medical X-rays are extensively used for diagnostic purposes.

b) Radio-isotopes are administered to patients during radiation therapy to destroy the diseased cells. Radio-isotopes are such isotopes of elements that emit ionising radiations.

c) The leackage from the core of nuclear reactors release nuclear radiations.

d) Radioactive wastes generated by nuclear power plants.

e) During the mining processes of radioactive ores of uranium and thorium, huge amounts of radioactive wastes are generated.

f) Radiations from researches on radioactivity e.g. a large no. of radioactive isotopes like C^{14}, I^{125}, P^{32} and their compound are largely used in scientific researches.

g) Nuclear accidents i.e. on 26.04.1986 the Ukrainian reactor at Chernobyl released a massive amount of radiations where innumerable people were died and several others suffered from cancer, leukamia due to radiation.

h) Nuclear disaster i.e. in 1945, during the course of IInd world war, the USA dropped atom bombs on the cities of Hiroshima and Nagasaki in Japan and till today the people suffer from the adverse effects of nuclear bombs.

i) A no. of nuclear explosions have already been made during the recent past is different parts of world. In an explosion, 50% of the energy goes to the blast, 33% as heat and the rest 17% or so to radioactivity. The most dangerous

materials in radioactive fall out are Sr_{90} (Strontium-90) and Cs_{137} (Caesium-137) which contaminate the environment for many years.

Effects of Nuclear Pollution

1) The acute radiation exposures cause sudden death, death after some weeks, loss of hairs, bleeding from gums etc.
2) High doses of radiation may damage to bone marrow and thus retard body's ability to fight against infections.
3) Brains of foetus is highly vulnerable to damage and may result in mental retardation.
4) High doses of radiation cause blood haemorrhage and ultimately death of the organisms.
5) Radioisotopes released into the environment accumulate in the air, water and soil and enter human body through food chain and its accumulation in the body may cause leukamia, bone cancer, and hereditary diseases.
6) Plants also show genetic changes due to exposure to radioactivity.
7) Atomic radiation can char wood and even ignite it with 16 km from the site of explosion.The temperature increases so high and metals and minerals not only melt but will vapourise.
8) The areas subjected to radiations have reduced bio-diversity.

Control of Nuclear Pollution

1) All the precautions must be adopted in the use of radioactive substances.
2) Manufacturing and the use of nuclear weapons must be stopped.
3) Nuclear tests and further development should be suspended.
4) The design of existing and proposed nuclear power station is so that any radiation can not spread even in any accident.
5) Ocean dumping of nuclear wastes should be checked strictly.

6) People in industry, research and medicine using radionuclides must be protected from exposure to radiation by more suitable means.

7) There must be proper and safe disposal of nuclear wastes.

Bioremediation

Bioremediation is the removal of pollutants from the biosphere by using the biological processes. The microorganisms in particular and some higher plants have the abilities to degrade, detoxify and even accumulate the harmful organic as well as inorganic compounds. Thus Bioremediation is the name given to the use of bacteria and other small organisms and also higher plants to clean up or reduce unwanted concentrations of certain substances. The basic principle of bioremediation is natural attenuation (or intrinsic bioremediation). **Natural attenuation** is natural occurring process to reduce the mass, toxicity, mobility, volume or concentration of contaminants in an environment without human intervention. In most of the cases the alternation or manipulation of physical and / or chemical properties of the contaminant or factors is used to enhance the natural processes. This is referred to as enhanced bioremediation. There are two approaches for enhanced bioremediation viz.:

a) **Biostimulation** : Primarily it depends on the modification of the environment.

b) **Bioaugmentation** : It uses the addition of microbial cultures to increase biodegradation.

Some microbial degradation or transformation occur only in the absence of oxygen. The dry anaerobic composting (Dranco) process converts the organic parts of biodegradable organic solid waste and refuse into energy in the form of biogas (Methane and carbon dioxide) and a humus like material by a group of anaerobic bacteria like methanogens (methane producing archeobacteria). This Dranco process is used at Brecht, Belgium and Salzburg, Austria. The bioreactor which removes nitrate from water has been tested at Blankaart, Belgium. This bioreactor contains the methylotrophic bacteria like *Methylophilus methylotrophus* to carry out denitrification. Methanol is first added to bioreactor to support the growth of methylotrophs. Bacteria like *Pseudomonas cepacia* are capable

to biodegrade chlorinated hydrocarbons present in effluents of pesticide industries manufacturing DDT, heptachlor, chlordane etc. In Matera (Italy), waste water is treated anaerobically in a bioreactor that produces epoxy resins from epichlorohydrin and phenolics. A bacterium *Acetobacter liquefaciens* S-1 is used to treat waste water in textile and dye industries in Hong Kong. In bioscrubbers and biotrickling filters, multiple microbial communities are grown on solid surfaces to produce multilayered complexes called **biofilms**. When gas streams having organic pollutants are passed through biofilms/biofilters, the pollutants are degraded. Biofiltration has been used to treat gases given off by soybean toasters in Hengelo (Netherland) since 1989. For the treatment of volatile organic compounds in air, some fungi like *Candida tropicalis* are exploited in biofilters. The mycelium of the fungi provides a large surface area and thus greater capacity to eliminate pollutants. A ceramics factory of Southern Germany uses biofilters to remove more than 99% of the ethanol and isopropyl alcohol released into air from drying ceramics. Airborne hydrocarbon vapours are readily treated with biofilters.

The crude oil spills at the sea are perhaps the most widely covered environmental incident which cause alarming threats to biodiversity and human health. The safest way of treating an oil slick is bioremediation where microbial surfactants are sprayed from the air which emulsify after mixing with the oil and oil spill is dispersed throughout the water body so thinly that it no longer remains hazardous. Bacteria and yeasts can grow on several fractions of hydrocarbons as heptane, decane, hexadecane etc. Professor Ananda M. Chakrabarty, working at the University of Illinois Medical Centre, Chicago, USA has developed many strains of oil eating bacteria. He developed a very efficient oil eating '**Superbug**' using species of Pseudomonas through recombinant DNA technology. The successful bioremediation of shorelines affected by the oil spill from the Exxon Valdez in Prince William Sound, Alaska (USA) in 1989 was the largest bioremediation project to date where more than 111 km of shoreline was treated. The slow-release formulations of inorganic nutrients, primarily ammonium nitrate and ammonium phosphate, were distributed throughout the oiled zone which stimulated the metabolism of

indigenous hydrogen-degrading microorganisms and degraded both surface and subsurface oil 3 to 5 times faster than occurred at untreated test sites. Petroleum hydrocarbons contaminants of land and groundwater were removed by air sparging and bio-venting. **Air sparging** is the injection of air to stimulate aerobic degradation and volatilization. **Bioventing** means the contaminated water is pumped to the surface and reinjected.

Microbial remediation of metals and radionuclides contaminated soil and sediments can be achieved by

a) immobilisation of metal in situ to reduce metal bioavailability and mobility or

b) removal of the metals and radionuclides from the contaminated soils and sediments.

Microbes like *Thiobacillus ferroxidans* remove metals from soils through metal solubilization or leaching. Bioleaching is used to recover Cu, Pb, Zn and uranium. Some surfactants like rhamnolipid produced by *Pseudomonas aeruginosa* showed specificity for Cd & Pb. Emulsion produced by *Acinetobactor calcoaceticus* helps in removal of metals. Several toxic heavy metals may be removed from industrial effluents by using *Pseudomonas putida, Arthrobacter viscous* & *Citrobacter* spp. Uranium & thorium like radioactive metals are removed by *Rhizopus arrhizus, Penicillium chrysogenum* (radium), the yeast *Saccharomyces cerevisiae* (uranium). Bioleaching of Zn, Co, & Ni from sulphide rocks is brought about by the bacteria like *Thiobacillus thiooxidans*.

Phytoremediation : Phytoremediation is the use of vegetation to remove, accumulate, degrade, contain or immobilize harmful pollutants from the soil or water. It relies on the plants ability to act as a solar-driven pumping and filtration system and enhances or stimulates the natural tendency of ecosystem to restore itself. Some plant species have the unique ability to uptaken, tolerate and even hyperaccumulate heavy metals and other toxic substances from soil and water through their roots and concentrate them into roots, stems and leaves e.g. some aquatic weeds like Salvinia, Lemna, Azolla and Eichhornia, sedges like *Typha latifolia* and some herbaceous and woody flowering plants. The alpine pennycress *Thlaspi caerulescens* when grown on zinc-contaminated soil, yields

30-40% zinc which is as high as highgrade ore. Thus this plant is **bio-ore of Zn**. A variety of tree *Sebertia acuminata* (Sapotaceae), native of new Caledonia, accumulates 20-25% nickel of its dry weight. This plants bleeds a bluish green latex, i.e. sap. Phytoremediation processes are grouped under six main categories viz.- Enhanced rhizosphere degradation, phytodegradation, phytoextraction (Phytoaccumulation), Rhizofiltration, Phytovolatilization and Phytostabilisation.

Table : Categories of Phytoremediation

Phytoremediation Categories	Technology	Media	Suitable Plants Tested
Enhanced rhizophore degradation	Degradation of the contaminant by plant rhizophore microorganisms	Mainly soil, sediments, and sludge, but also surface and ground water.	Grasses, hybrid poplars, red mulberry, alfalfa, cattails
Phytodegradation	Degrdation of a compound through plant metabolism or through the release of enzymes by the plant	Soil, sediment sludge, ground andd surface water	Algae,stonewart,
Phytoextraction	Plants accumulate metals and radion-uclides and trans-locate them to their harvestable parts.	Soil, sediment, and sludge	Indian mustard, alpine pennycre-ss, sunflowers, poplars
Rhizofiltration	Plants absorb or precipitate metals and radionuclides from aqueous solutions around the roots, therefore immobilizing the metals or radionu-clides.	Surface or ground water	Sunflowers, Indian mustard, water hyacinth
Phytovolatilization	Uptake and possible transformation of a compound by the plant and subsequ-ent release into the atmosphere	Groundwater, soil, sediment, and sludge	Poplar, alfalfa, black locust, Indian mustard
Phytostabilization	Stabilization of the metal-contaminated soil by plant roots reducing the move-ment off-site.	Soil	Indian mustard, grassses, hybrid

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Table : Some technological definitions relevant to bioremediation

Technology	What does it means
Air sparging/ Aquifer sparging/ Biosparging	Injection of air to stimulate aerobic degradation. May also stimulate volatilization.
Air striping	Injection of air to stimulate volatilization. contaminant is usually removed by subsequent adsorption.
Aquifer bioremediation	In situ bioremediation in an aquifer, usually by adding nutrients or co-substrates through injection wells.
Aquifer sparging	Injection of air into a contaminated aquifer to stimulate aerobic degradation. May also stimulate volatilization.
Batch reactor	A bioreactor loaded with contaminated material, and run until the contaminant has been consumed. It is then emptied, and the process is repeated.
Bioactive barrier/ Bioactive zone/Biowall/ Wall-and-gate	A zone, usually subsurface, where biodegradation of contaminant occurs so that no contaminant passes the barriar. Sometimes impermeable walls funnel contaminants to this reactive zone.
Bioaugmentation	Addition of exogenous bacteria with defined degradation potential (or rarely indigenous bacteria cultivated in a reactor and reapplied).
Biofilm reactor	A reactor where bacterial communities are encouraged on a high surface area support. Biofilms

	often have a redox gradient so that the deepest layer is anaerobic while the outside is aerobic, allowing both aerobic and anaerobic processes to occur.
Biofiltration	Usually, an air filter with degrading organisms supported on a high surface area support, such as granulated activated carbon or compost
Biofuffing	Augering soil to increase porosity
Bioleaching	Extracting metallic contaminants at acid pH, perhaps while attempting to optimize fungal degradation of organic contaminants.
Biological fluidized bed/ Fluidized bed bioreactor	Bioreactor where the fluid phase is moving fast enough to suspend the soild phase as a fluidlike phase
Biological plug	In ground actively aerated bioreactors containing adapted microbial consortia to degrade contaminants concern.
Biopile, soil heaping	An engineered pile of excavated contaminated soil, with engineering to optimize air, water and nutrient control.
Bioslurping	Vacuum extraction of the floating contaminant and water, and vapour from the vadose zone. The airflow stimulates biodegradation.
Biostimulation	Optimizing conditions for the indigenous biota to degrade the contaminant.
Biotransformation	The biological conversion of a contaminant to some other form, but not to carbon dioxide and water.

Biotrickling filter	A reactor where a contaminated gas stream passes up a reactor with immobilized microorganisms on a solid support, while nutrient liquor trickles down the reactor.
Bioventing	Vacuum extraction of contaminant vapours from the vadose zone, thereby drawing in air to stimulate the biodegradation of the remainder
Borehole bioreactor/ In well bioreactor	The addition of nutrients and electron acceptor to stimulate biodegradation in situ in a contaminated aquifer.
Closed-loop bioremedation	Groundwater recovery, a bioreactor, and low-pressure reinjection to maximize nutrient use, and maintain temperature in cold climates.
Composting	Addition of biodegradable bulking agent to stimulate microbial activity. Optimum composting generally involves self-heating to 50-60°C.
Constructed wetland	Artificial marsh for bioremediation of contaminated water.
Continuous stirred tank reactor (CSTR)	A bioreactor that is completely back mixed.
Digester	Usually, an anaerobic bioreactor that generates methane.
Ex-situ bioremediation	Usually, the bioremediation of excavated contaminated soil in a biopile, compost system or bioreactor.
Fixed-bed bioreactor	Bioreactor with immobilized cells on a packed column-matix.
Land-farming, Land treatment	Application of a biodegradable slude as a thin layer to a soil to encourage biodegradation. Tilling and fertilizing is usually required.

Natural attenuation/ Intrinsic bioremediation	Unassisted biodegradation of a contaminant
Pulsed bioremediation	Alternating injection of a co-substrate for the contaminant, and oxygen.
Pump and treat	Pumping groundwater to the surface, treating, and reinjecting.
Rhizosphere bioremediation	Stimulating the bacteria in the rhizosphere (root-zone) to carry out biodegradation of a soil contaminant.
Rotating biological contactor	Bioreactor with rotating device that moves a biofilm through the bulk water phase and the air phase to stimulate aerobic degradation.
Sequencing batch reactor	Periodically aerated solid phase or slurry bioreactor.
Soil vapour extraction	Vacuum assisted vapour extraction.

Courtesy : Ecology & Environment by P.D. Sharma

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4 Disaster and Disaster Management

Disaster is the widespread destruction of life and property. People all over the world are affected by disasters that occur now and then. Disaster may be defined as natural or man-made event which result in large scale loss of life and property. Disaster, can be either sudden in nature or occur gradually e.g. flood may be either sudden or gradual. Disasters are generally categorised under two heads viz. Natural disasters and Man-made disasters.

- Disasters
  - Natural
    - Earthquakes, volcanoes, land slides, Tsunami waves
    - Floods, droughts, cyclones, cold waves, snowfalls, hails, thunderstorms
  - Man made
    - Natural Hazards : Landslides, soil erosion, Droughts, water logging,
    - Social Hazards : like war, riots, epidemics, nuclear explosions, terrorism, accidents etc.
    - Biological hazards : population explosion, non-curable diseases.

Natural disasters are such events which occur naturally like earthquakes, Tsunami waves, floods etc. Man-made disasters are such events which occur mainly due to human activities like road accidents. India has the highest accident rates in the world. In India, 70% are road-accidents and nearly 80% of the road accidents occur due to bad driving and human error.

Earthquakes : Earthquake is the sudden shaking earth's surface caused by abrupt release of slowly accum stress. Tectonic plates found in the interior of the earth with each other due to their movement and cause earth The place of origin of earthquake is called 'focus' which lies inside the earth. The intensity of earthquake is measur Richter scale from 0 to 9.

Generally earthquake of intensity lower than 5.4 on scale is not hazardous. For the first time Charles Rich America made a scale to study earthquake which is kno Richter scale.

Intensity of earthquake		Effects
Ritcher scale	Its type	
4.9-5.4	Strong	Loose articles are started down, Bus, Jeep, car are slippe cracks may appeared on bui dams and bridges.
5.5-6.1	very strong	
6.2-6.9	Destructive	buildings with weak foundat with no support crumble down
7.0-7.3	Disastrous	Cracks may developed in railway tracks may curved, lan on steep slopes.
7.4-8.1	very disastrous	Most of the buildings are cr down, bridges may be break floods are occurred in the riv to land slides. Roads, railwa pipe lines and cables m distorted and damaged.
8.1-more	Catastrophic	It is a catastrophic earth Folding & cracks are occurred ground, water & sand come o the cracks, Almost all the ma structures like roads, railway buildings etc are severly da and collapsed.

Land slide: Landslide is the sudden downward movement of land or rocks due to gravitational forces in mountainous or hilly regions. When the grip gets loosened, the loose earth or large mass of rocks generally slide. It is a recurrent phenomenon in hilly regions. Rainfall or snowfall is the major cause of landslide but human activities like mining and deforestation are also responsible.

Effects

i) Landslide blocks the roads and virtually crushes everything in its path.
ii) It blocks the river and the occurence of flood.
iii) It causes a great loss of life and property.
iv) Communication system is severely damaged.
v) Agriculture, poultry etc. are also affected.

Floods

Flood means the submergence of an area due to heavy rains, overflowing rivers, cyclones, tsunamis, melting of snow or dam burst. In India, heavy rains and landslides are responsible for more than 58% of all disaster loss. Deforestation increases the frequency and intensity of floods as the absence of trees leave no obstruction in the path of the river. Bangladesh is a highly flood prone country.

Effects

1) The mud houses and huts and even the pakka concrete buildings are washed off by flood streams.
2) The roads, railway tracks, bridges, cables, electric poles etc. are also badly affected and sometimes flown away with flood water.
3) To get clean & clear water becomes a problem.
4) The standing crops are damaged and destroyed.
5) Power lines and communication and transportation systems are badly affected.
6) The decomposition of organic materials results in foul odour and avails the favourable environment for the spread of malaria, Diarrhoea, cholera etc. like diseases.

7) Ecosystem of the area is affected.
8) Sometimes it causes deluge.

Drought

Drought is the specific type of condition for a particular region where the amount of rainfall is either scanty, nil or below the normal over a longer period. Thus it is a long spell of scanty or no rainfall. Large scale of deforestation affects the climatic conditions of the region.

Effects

1) Crop failure due to water crisis.
2) Famine due to loss of crops.
3) Large scale of death due to starvation.

4) Rise of inflation due to shortage of supplies.
5) Drying up of wells, falling of ground water level, shortage of water in the river.
6) Loss of timber and dairy.
7) Widespread unemployment.

Cyclones

A cyclone is an area of low atmospheric pressure characterised by inward spiraling winds that rotate counter clockwise in northern hemisphere and clockwise in the southern hemisphere of the earth. Cyclones are generally associated with high speed winds and heavy rainfall.

Cyclone spreads from sea to land and generally affects the coastal areas. Cyclones are more common in tropical regions because of high temperature and high humidity. Cyclones are called **typhoons** in Pacific Ocean, China and Japan; **cyclones** in North Atlantic and Indian Ocean and **Tornado** or **Hurricanes** in North America, **Willi-Willies** in Australia. About 65-75 cyclones are developed every year around the globe. About 5-6 cyclone originate in the Bay of Bengal and the Arabian sea every year. East coast is more vulnerable than the west coast. Cyclones are destructive because of their associated hazards like high storm & tides, torrential rain and gales and sometimes even floods which cause heavy loss of lives and destruction of property, extensive damage to standing crops, loss of livestock and livelihood, reversal

of developmental gains having far reaching socio-economic and environmental consequences. Ships, shipyards and vehicles are also damaged. Civic facilities and communication systems are badly affected.

Disaster Management

Earlier disaster management mainly involved post disaster management activities. It mostly dealt with search and rescue operations, provisions of relief to persons affected by the disaster and finally their resettlement. Thus there are four components of disaster management.

1. Preparedness
2. Relief and response
3. Recovery and rehabilitation
4. Prevention

Past experiences are quite helpful in identifying some major areas which are prone to earthquakes, landslides, floods, droughts, and cyclones. This can be of immense help for future planning regarding the management of disasters. Presently, disaster management is getting much attention and also involves programmes related to public awareness. First of all, the hot spots for a particular type of disaster are identified and information is collected about disasters that have occured in the past, the extent of damage done and other such aspects. All these things enable us to assess the frequency and intensity of the disaster. In all the natural disasters, rescue and relief operations could be more successful and effective if complete information about the extent of damage is gained.

Earthquake management

Of all other natural calamities, earthquake is the one which requires medical facilities most urgently. The toll of physical injuries goes very high and some of the casualties occur only because of delay in providing medical facilities.

i) Rescue and relief operations and adequate medical facilities can reduce damage caused to human life and property.

ii) To get the informations about earthquake, there are 212 seismograph centres in India. Prior informations can be given to the people after geting the information.

iii) In 1983, Govt. of India made buildings construction code. The building codes prescribed by the Bureau of Indian Standards should be followed strictly. Building plans should be checked by Municipality.

iv) Properly designed earthquake resistant buildings and other structures can prevent may buildings from falling down. This reduces the number of casualties.

v) It is important to sensitise people on the need to construct disaster resistant houses and for preparedness. Training should be provided for :

A→ Architects	B→ Builders
C→ Contractors	D→ Designers
E→ Engineers	F→ Financiers
G→Govt. functionaries	H→ House owners

vi) The following safety measures are to be followed during the earthquake.

a) If you are in the house and unable to go out quickly; you should shift yourself quickly under the table or cot and in the corner of the room.

b) Move away from the glass-window.

c) Switch off the main switch of your house.

d) Do not touch any electric wire.

e) Move out quickly from the house and remain in the open space until the shaking of earth is stopped.

f) obey the guidelines communicated by the media.

g) Move away from the big buildings, trees, electric poles.

i) Stop quickly the vehicle on the road aside and trains on the railway track.

Landslide management

i) Landslides are more common in hilly regions, so long-term land use planning is quite helpful.

ii) People should avoid living under on overhanging mass of rocks and soils. Such a land can be used for agriculture and other purposes.

iii) Development of plant cover on loosened rock fragments is one of the most effective landslide mitigation measures.

iv) Building should be equipped with adequate system of rescue and relief measures and there should be at hand medical facilities as far as possible.

v) First aid and other facilities should be instantly provided to the physically injured.

vi) Landslide prone areas should be covered by iron net along the sides of railway tracks and roads.

Flood management

To study the reasons for coming floods, damages caused by it and flood control measures, Govt. of India commissioned a National Flood Commission in 1976. Flood management has two dimensions viz.,

A) Flood control measures and B) rescue and relief operations.

i) These are the following flood control measures :-

a) Construction of small dams on the rivers.

b) Raise and strengthen the side dams.

c) Control the water discharge of river by making canals.

d) Removal of unwanted silt from the river and thus increasing the depth of river which enhances the water carrying capacity.

e) Construction of bigger dam is avoided which increases the water load on the earths' surface.

f) Reforestation programmes should be carried out.

ii) Houses in flood prone areas should be vacated before the arrival of flood and Houses are to be built on plateforms or elevated areas.

iii) Sand bags can be used for redirecting the water flow in the event of flood.

iv) Flood forecasting and warning systems should be installed. Flood warning in India is issued by Central Water Commission (CWC), irrigation, Flood Control Department and water resource department.

v) Immediate rescue operations for the people surrounded in the flood by employing boat, helicopter or any other means.

vi) Medical facilities should be availed to the flood affected people.

vii) Relief operation should be carried out at each and every level.

Drought management

i) Afforestation and reforestation programme should be implemented honestly so that green shelter belts are developed.

ii) Adoption of water-harvesting measures.

iii) Buffer stocks of food grains are to be maintained.

iv) Multipronged drought prone area programmes are to be followed.

v) Control of population explosion.

vi) Control of soil and water erosion.

vii) Watershed management.

Cyclone Management

Cyclones can strike anywhere along the coastline during pre-monsoon and post-monsoon months. Proper rescue and relief operations are the only options when disaster strikes.

i) Establishing a state-of-the-art cyclone early warning system (EWS) involving observations, predictions, warning and user friendly advisories.

ii) Commissioning of the National Disaster Communication Infrastructure (NDCI) to provide dedicated and failsafe communications to the National, State and District Disaster Management Authorities and official concerned.

iii) Expanding the warning dissemination outreach by introducing 'Laste Mile Connectivity' which will include providing public address system along the entire coastline, using VHF technology. This will be done along with putting in place all other options currently in voague internationally.

iv) Implementing the National Cyclone Risk Mitigation Project (NCRMP) in all the 13 coastal states and UTs. The objective of NCRMP is to strengthen structural and non-structural

cyclone mitigation efforts and capacity building so as to reduce the risk and vulnerability of the coastal districts which are cyclone prones. NCRMP has three major components:

a) Strengthening of dissemination system of cylcone warning and advisories from source, districts/sub-division level to the community.

b) Cyclone risk mitigation investment which has identified nine sub-components : -construction of cyclone shelters, saline embankments, roads, plantation of mangroves and shelter belts etc.

c) Technical assistance for hazard risk management and capacity building.

v) Taking up structural mitigation measures like improving structural lifeline infrastructure, construction of multi-purpose cyclone shelters and cattle mounds, ensuring cyclone resistant design standards in rural and urban housing schemes, building all weather road links, bridges, culverts and saline embankments etc.

vi) Management of coastal zones to include mapping and delineation of coastal wetlands, patches of mangroves and shelterbelts and identification of potential zones for expanding bio-shields spread based on remote sensing tools.

vii) Setting of exclusive eco-system monitoring network to study the impact of climate change.

viii) Establishing a comprehensive 'cyclone disaster Management Information system' (CDMIS) covering all phases of disaster management.

ix) Setting up of a National Cyclone Disaster Management Institute (NCDMI) in one of the coastal states to address all issues related to cyclone risks.

x) Commissioning of Aircraft probing of cyclone (APC) facility to fill critical observational data gaps and significantly reduce the margin of error in predicting cyclone track, intensity and rainfall.

Tsunami

Tsunami is a Japanese word meaning the waves created near the port.

Tsu + nami → Tsunami
|| ||
means   means
|| ||
Port   waves

Such waves are created after the earthquakes and volcanic erruptions on the bottom of the ocean, and as a resultant, very intense high tides are created which are knowns as Tsunamic waves. Due to Tsunamic waves on 26 Dec 2004, the coastal areas of India, Indonesia, Malaysia, Srilanka, Thailand, Myanmar, Maldives & Bangladesh were severly damaged and destroyed. An 8.9 magnitude earth quake off the coast of NE Japan spawned a Ferocious tsunami that's caused massive destruction, flattering whole cities starting ranging fires killing hundreds on march 11,2011

Tsunami Management

After the Tsunami hazard, Govt. of India made a National Disaster Management Authority (NDMA) under the chairmanship of the Prime Minister on 28 Dec 2004. Some suggestions of NDMA are :

i) 26 Countries are interlinked by a network which give informations prior to natural calamities. India should be one of the member country.

ii) To get disaster sensitive system from America.

iii) Planting of trees in the coastal belt and such coastal shelter belts reduce the intensity of tsunami.

iv) All the cyclone management measures are to be adopted.

Man-made Disasters

Man is the slave of lust, hatred and deception and thus man is not free from errors. Negligence, misuse of equipment, misuse of knowledge and science achievement, lack of proper precautions and terrorist activists cause several disasters.

Chemical and Industrial Accidents

Such accidents are occurred due to sudden release of chemicals due to technical fault, negligence or due to geological hazards.

Effects

i) Several people die and get injured due to toxic substances. These toxins can cause cancer, heart failure, loss of eyesight etc.

ii) These accidents pollute air, water and land resources and disturb the ecological balance.

Mitigation strategies

i) Local populace should be aware in case an accident occurs.

ii) Regular checking and proper maintenance of industries and factories should be undertaken.

iii) Warning systems should be installed.

v) Industries should be located away from residential areas.

Nuclear Disaster

In 1945, the first nuclear disaster occurred in the history of the world when the first atom bomb was dropped on 6 Aug 1945 on a Japanese city Hiroshima. The disaster left an undelible mark on the mind of the people. The bomb not only destroyed all structures and life but also contaminated all the resources.

Three Mile island nuclear power plant leakage in U.S.A. in 1979 and 'melt down' of Chernobyl nuclear power plant in earstwhile USSR in 1986 are the examples of nuclear disasters.

The ways of preventing such nuclear disasters are :

a) All the nations should have agreed on not to use nuclear weapons in the future.

b) Proper and adequate safety measures must be adopted at the nuclear power plant.

Epidemics or Biological hazards

Epidemic means the large scale spread of infectious diseases. The threat of an epidemic is even greater than the disasters like earthquake, tsunami, flood and cyclone. Use of biological weapons may create epidemic. People living in slums are especially prone to such diseases due to poor sanitation facilities.

Epidemic Management

i) Community people should have understanding of their roles in public health system.

ii) People should get their children vaccinated at regular intervals.

iii) Medical team should have a contigency plan in case an epidemic break.

iv) Proper sanitation facilities

v) Good hygienic conditions and basic health care

vi) Cigarette, bidis and pan etc should not be used.

Mechanical disasters

Such disasters are occurred due to mechanical faults and driving errors. Rail accidents are due to faults in rail tracks, railway bridges, non-vigilent of railway staff and sometimes due to unsocial elements. The accident of roadways and smaller vehicles is due to drunken driving, engine faults, foggy weather etc. The aeroplanes are crashed due to engine faults and birds-collision.

To avoid such accident proper use of driving guidelines and careful driving are strictly followed.

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5 Water Relation

Introduction

Plant physiology is the study of vital or functional activities of plants. And water is essential for these functional activities.

What for water is needed-

1) Water is absolutely essential for protoplasm because its hydration is essential for its proper organisation and proper functioning of its organelles.
2) Water is the carrier of various dissolved substances like gases, minerals, organic and inorganic substances etc.
3) Water is necessary for metabolic reactions of the cell e.g. photolysis of water.
4) The rigidity and turgidity of cells is maintained by and large by water.
5) Water forms a continuous network throughout the plant through which dissolved substances move up.
6) Water makes up the loss of water during transpiration and guttation.

Thus almost all the functional activities of plants depend on the water relation. Under water relation we study the following points-

a) How does water enter into the plant:- This functional activity is studied under the heading '**Osmosis**'.
b) How does water move up inside the plant:- It is studied under '**Ascent of sap**' or '**Translocation of sap**'.
c) How is water lost from the plant:- It is studied under '**Loss of water**' or '**Transpiration**'.

Diffusion: The movement of the molecules of gases, liquids or solutes from the regions of higher concentration to the regions of lower conc. until the molecules are evenly distributed throughout the available space is known as Diffusion.

Osmosis

- ★ Osmosis is essentially a special type of diffusion of liquids.
- ★ The term 'Osmosis' was given by Abbe Nollel.
- ★ Osmosis means:
  - a) Movement of **solvent.**
  - b) From a region of **lower** concentration of solution.
  - c) To a region of higher conc. of solution.
  - d) Through **semi-permeable membrane** (SPM).
- ★ Plasma or cell membrane is a semi-permeable membrane. At higher temperature plasma membrane becomes permeable.

Illustration:

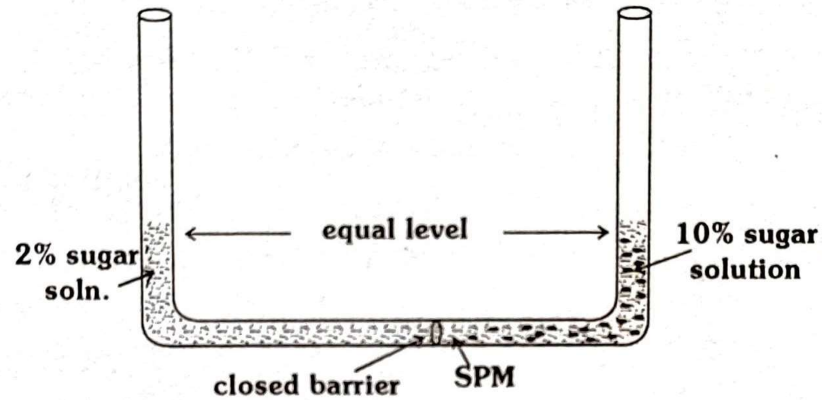


Fig : Closed barrier showing no-osmosis

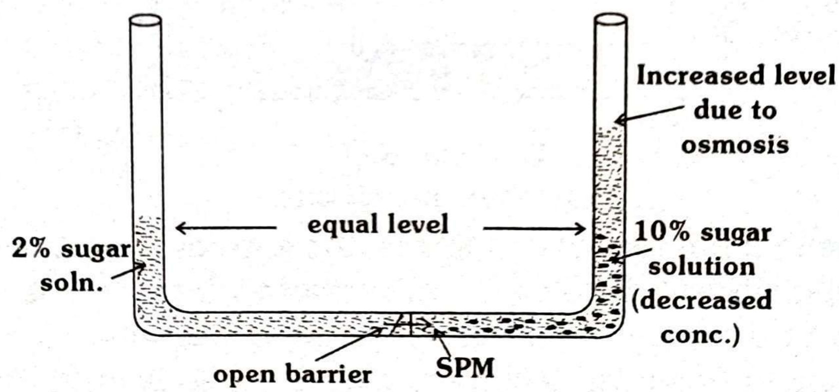


Fig : Opened barrier showing osmosis through SPM

Here when barrier between two different concentrated solution is opened and barrier remained only semi-permeable membrane, then the level of higher conc. solution is increased. It is happened only due to flow of water from lower conc. to the higher conc. through semi-permeable membrane.

★ Semi-permeable membrane is such type of membrane through which solutes of solution do not pass but solvent passes e.g. plasma-membrane.

★ Differentially or Selectively Permeable membrane is such type of membrane through which some particles pass but others do not pass e.g. lipo-protein cell membrane.

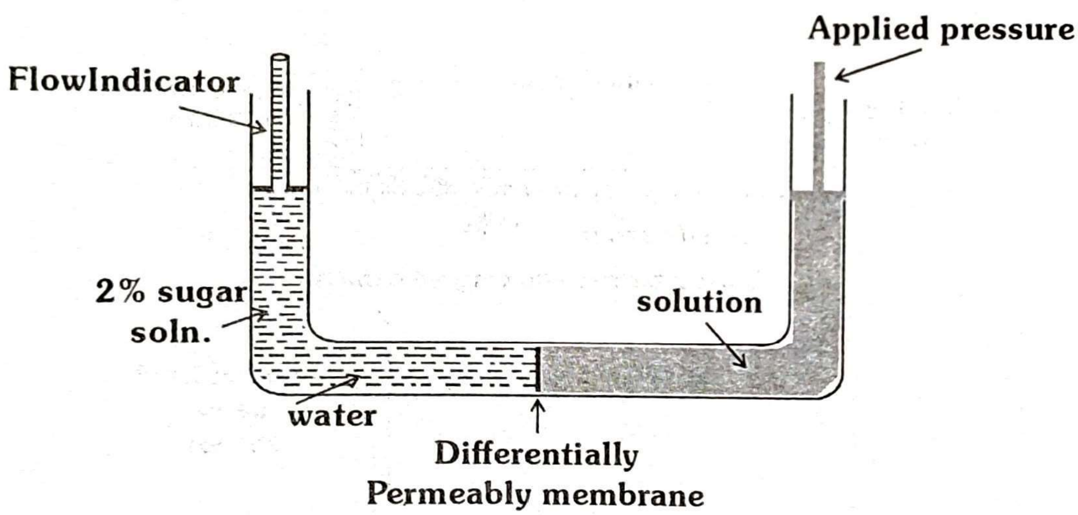
Osmotic Pressure or Osmotic Potential (O.P.):

The applied pressure required to stop osmosis when a solution is separated from pure water by a semi-permeable membrane is called osmotic pressure and usually denoted by 'π'.

The osmotic pressure of a solution is defined as the excess hydrostatic pressure which must be applied to it in order to make its water potential equal to that of pure water.

One atm. (S.I. unit of pressure) = 1.01 bars

or one bar = 0.987 atm.



Due to a number of definitions, the term osmotic pressure is misleading since it denotes a real pressure where as it is only a property of a solution expressed in terms of pressure. Hence the term 'Osmotic Potential' is used by modern physiologists. Osmotic potential is that part of water potential which becomes more negative with addition of solutes.

Osmotic Potential = negative osmotic pressure.

It indicates decrease in pressure that occurs due to addition of the solutes. In a pure solvent, the value of osmotic potential is **Zero** which is maximum value.

Diffusion Pressure Deficit/Water Potential (DPD/WP):

Diffusion pressure deficit (DPD) is also called suction Pressure (S.P.). It is the ability of a cell to draw water. It is the force per unit area (i.e. pressure) by which water enters into a cell. A pure solvent is supposed to have maximum diffusion pressure. When certain solute particles are added to the pure solvent, the diffusion pressure of the resulting solution is lowered. The amount by which the diffusion pressure of a solution is lowered than that of its solvent at the same temperature and atmospheric pressure, is called DPD. The term DPD was introduced by Meyer in 1938.

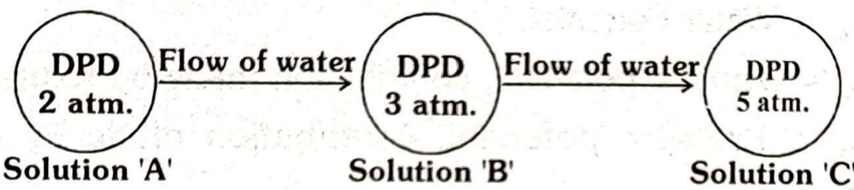


Fig. : Movement of water is from A to B and B to C

But according to the recent trend, diffusion of water is explained in terms of **Water Potential**. DPD is the positive value whereas water potential is the negative value.

Turgor Pressure (T.P.) : T.P. is the outward pressure exerted by the cell solution on the cell wall which is developed due to osmotic diffusion of water. In an equalibrium inward pressure is also given by the cell wall on the cell solution in an equal amount, which is called wall pressure or Hydrostatic Pressure.

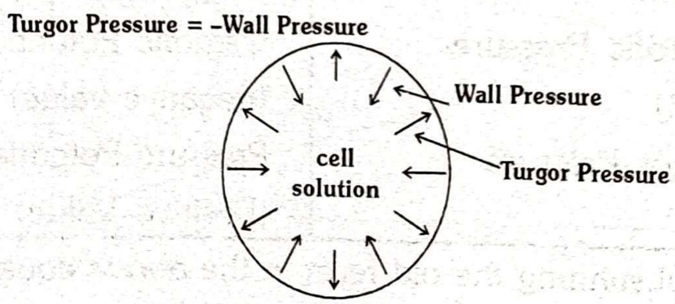


Fig. : Turgor Pressure

Turgor Pressure is also called **Pressure Potential** (P.P.) which has positive value.

Chemical Potential : The free energy per mole of a chemical substance is called its chemical potential. Chemical potential of water in a solution is reduced by the addition of solutes.

Osmotic Relations : The diffusion of water depends upon its free energy per mole. The wall pressure also increases the free energy of the water contained in a cell. The sum of osmotic potential and wall pressure denotes a net change in the chemical potential of water. This net change is called **water potential** (Ψ_w). Water potential (W.P.) is **always negative** and the maximum value is **zero**. Water potential is affected by osmotic (solutes) potential, pressure (hydrostatic or turgor) potential and Matric potential (due to water binding matrix).

$$\psi_w = \Psi_s + \Psi_p + \Psi_m$$

Ψ_w = Water Potential.

Ψ_s = Osmotic potential; contribution made by solutes.

Ψ_p = Pressure potential; contribution made by turgor pressure.

Ψ_m = Matric potential; contribution made by matrix.

Since Ψ_m is negligible,

$$\psi_w = \Psi_s + \Psi_p$$

$$\Rightarrow \boxed{WP = OP + PP}$$

S.No.	Old term	New Term
1.	Diffusion Pressure Dificit (DPD)	Water Potential i.e. W.P. (negative value)
2.	Osmotic Pressure (O.P.)	Osmotic Potential, i.e. O.P. (negative value)
3.	Turgor Pressure (T.P.)	Pressure Potential i.e. P.P. (Positive Value)

After substituting the old term in the above equation-

WP = OP + PP

=> – DPD = –OP + TP

=> $\boxed{OP = TP + DPD}$ here OP → osmotic pressure.

=> Osmotic Pressure = Turgor Pressure + Diffusion Pressure Dificit.

Therefore in osmosis, movement of water takes place from:-

a) higher water potential to lower water potential.
b) lower concentration to higher concentration of solution.
c) Lower DPD to higher DPD.

Question : A cell (A) having O.P. = 10 atm. and TP = 4 atm. is surrounded by 'B' cells of OP = 18 atm. and TP = 6 atm; then movement of water is

a) From 'A' cell to 'B' cell (surrounding cell)
b) From 'B' cell to 'A' cell.
c) Both of them.
d) No movement of water.

Solution:

For 'A' cell: WP = OP + PP (or TP)

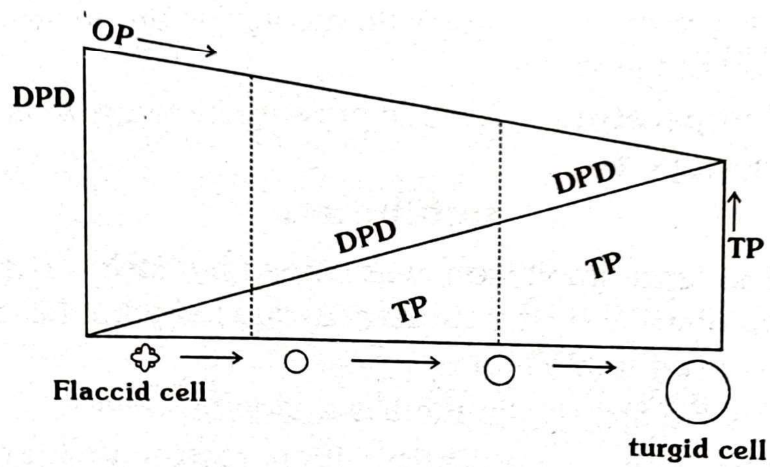
= –10 + 4 = – 6 atm.

or DPD = OP – TP = 10 – 4 = 6 atm.

for 'B' cell : WP = –18 + 6 = –12 atm.

or DPD = 18 – 6 = 12 atm.

therefore, movement of water is from 'A' cell (i.e. higher W.P. or lower DPD) to 'B' cell (i.e. lower WP or higher DPD) means Ans. (a)



When T.P. increases, the corresponding DPD decreases.

Endo osmosis : The diffusion of solvent particles into a living cell or structure is called endoosmosis.

Exoosmosis : The diffusion of solvent out of a living cell or structure is called exoosmosis.

Role of Osmosis :

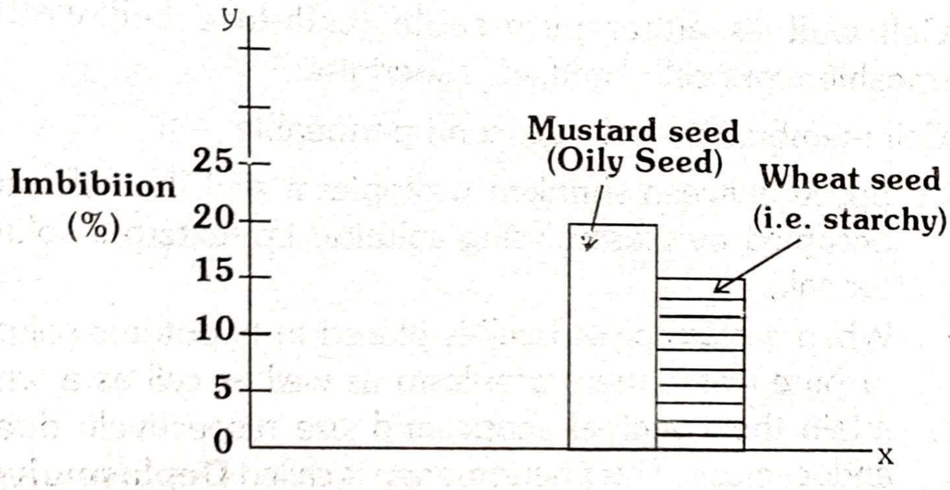
i) Plants absorb large amount of water from soil.
ii) Movement and distribution of water across cells is due to osmosis.
iii) Osmosis is responsible for turgidity of plant cells. The leaf, flower & stem tip require turgor for maintaining their form.
iv) Turgor of the guard cells is absolutely essential.
v) It is essential for the growth of young cells.
vi) High osmotic conc. increases resistance of the plants to freezing temperature and dessication.
vii) It is responsible for turgor pressure in root xylem i.e. root pressure.

Factors affecting Osmotic Pressure :

1) **Concentration of the solute particles** : Osmotic pressure depends upon the ratio of solute and the solvent particles. The increase in the solute concentration, increases the osmotic pressure.
2) **Ionisation of the solute molecules** : Ionisation increases the number of solute particles.
3) **Hydration of solute molecules** : A solution which has hydrated solute molecules is of higher osmotic pressure than otherwise because the water molecules which are associated with the solute molecules are ineffective as a part of the solvent.
4) **Temperature** : Osmotic pressure increases with increase in temperature.

Imbibition

★ The term 'imbibition' was coined by Sachs. The soaking up of water by dry substances due to hydrophillic colloids is called Imbibition.
★ It is the first step in the absorption of water.
★ The rate of imbibition increases with increase in temperature.
★ Imbibition in oily seed is more than in starchy seed.



Imbibition pressure is also called **Matric Potential** (Ψ_m). Matric potential is the component of water potential which is determined by the attraction between water and hydrating colloid or gel-like organic molecules, cell wall etc. (collectively called matrix).

The matric potential is maximum (most negative) in a dry material. Both living and dead plant cells possess a large amount of carbohydrates, proteins, and polypeptides etc. which are hydrophillic colloids and therefore, have very strong attraction for water. Seeds rich in colloidal materials are very good imbibants.

Plasmolysis

1) Plasmolysis is the shrinkage of protoplasm due to outward flow of water in a hypertonic solution.
2) The point where plasmolysis just starts (not visible) is called incipient plasmolysis.

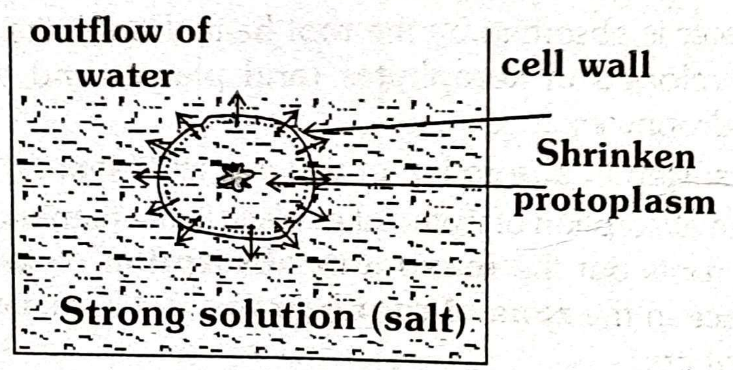


Fig. : Plasmolysis

Cell wall → either permeable (cellulose cell wall) or impermeable (cork cell, lignified, suberinised)

Cell membrane → always semi-permeable.

3) Space between shrinken protoplasm and the cell wall is occupied by plasmolysing solution i.e. external solution (or salt).

4) When a plasmolysed cell is placed in hypotonic solution or pure water, the protoplasm as well as cell as a whole attain their original shape and size respectively due to endoosmosis. This phenomenon is called **Deplasmolysis**.

Examples :

i) Raisins swell in water due to imbibition and endosmosis.

ii) Excess of fertilizer in the soil kills the plant due to plasmolysis (exoosmosis)

iii) Salted pickle or meat kills the bacteria due to plasmolysis.

Solution: is of three types:

i) **Hypotonic** solution : it means weak solution. A cell swells in hypotonic solution.

ii) **Hypertonic** solution : strong solution. A cell shrinks or become flaccid in such solution due to outward flow of water.

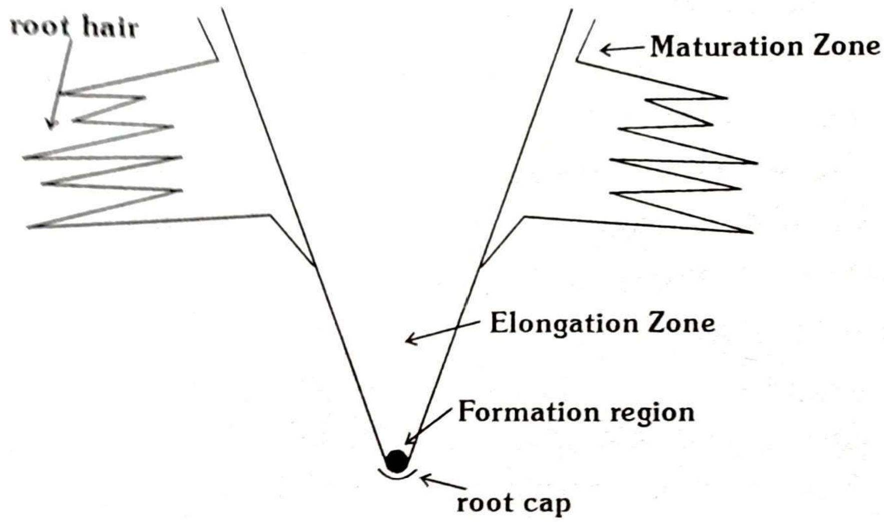
iii) **Isotonic** solution : not weak nor strong solution. A cell remains unchanged in it. Eye drops are always isotonic solution.

Absorption of water

1) Water is absorbed by the root hairs. Root hairs are more developed in xerophytes (arid plants) and absent in hydrophytes.

2) First step in absorption of water is imbibition.

3) The absorption of water takes place in the terminal portions of roots but the **maximum absorption** of water takes place in the **zone of root hairs** i.e. 1-10 cm. behind the root tip.



★ Root cap is formed by calyptrogen (=Dermatogen+Periblem)

★ Multiple root cap is found in Pandanus (screw pine).

★ Maximum absorption of **inorganic salts** is through the **zone of cell division.**

4) Renner (1912, 1915) :- First time recognised and classified the water uptake mechanism into "active absorption" and "passive absorption".

Types of Absorption

Active absorption — Passive absorption

Active absorption: Osmotic Theory — Non-osmotic theory

Table : Difference between Active & Passive absorption

Active absorption	Passive absorption
1) Occurs against concentation gradient.	1) along conc. gradient
2) Metabolic energy (i.e. ATP) is required	2) Spontaneous
3) Involves primary active transport using ATP and secondary active transport using proton motive force.	3) No
4) Always selective uptake e.g. ion uptake (NO_3^-)	4) Non-selective e.g. water.

Active Absorption :

1) Root hairs play an active role.
2) Water enters into root hair by osmosis.
3) Process occurs against the concentration gradient and
4) Metabolic energy is spent.

There are two major theories to explain active absorption :-

a) Osmotic Theory :

1) Atkins (1916) and Priestley (1920–22) were amongst the first to postulate an osmotic theory of active absorption.
2) The value of osmotic pressure of the cell sap of the root hairs is generally 2.0 atm. (but varies between 3 to 8 atm.) and of soil water is less than 1.0 atm.
3) Higher DPD of the cell sap of the root hairs causes endoosmosis of soil water.
4) But a problem is how a sufficient conc. of solutes is maintained in the root xylem to maintain a higher DPD in the xylem sap.

b) Non-osmotic theory :

1) Water is absorbed against a concentration gradient.
2) Absorption requires an expenditure of energy released from respiration.
3) Renner's active theory is called 'osmotic active'.

Passive Absorption :

1) Process occurs along the concentration gradient.
2) And hence energy is not involved.
3) Absorption is controlled by transpiration.
4) Highest DPD or Lowest Water Potential — in Leaf cells

   Lowest DPD or Highest water potential — in Root hairs

T/A Experiment :

T/A means Transpiration/Absorption ratio let,

i) Weight of bottle with plant = 1000g

ii) Initial reading of water inside tube is 5 cc. one drop of oil is poured into side tube to check evaporation. After allowing the minimum time i.e. 30 minutes for transpiration and absorption, again reading is noted down.

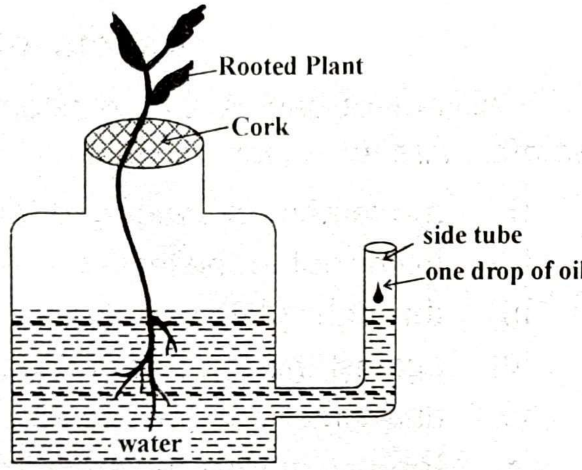


Fig. : T/A Experiment

iii) Wt. of bottle with plant = 998g.
means water lost = 1000 – 998 = 2g.

iv) Final reading of water inside tube = 3 cc.
means water absorbed = 5–3 = 2 cc.

$$\therefore \frac{\text{Transpiration}}{\text{Absorption}} = \frac{2}{2} = 1$$

Inference : water lost in transpiration is equal to water absorbed.

Factors affecting the rate of water absorption :

1) **Available Soil Water :** The rate of water absorption is uniform between the field capacity and permanent wilting percentage. The decrease in soil water below the permanent wilting point causes considerable decrease in the absorption of water.

2) **Conc. of the soil solution :** The lack of water absorption by plants growing in saline water is an example of physiological dryness.

3) **Soil aeration :** The rate of water absorption is rapid in well aerated soils. Oxygen deficiency and accumulation of CO_2 increases the viscosity of the protoplasm and decreases its permeability, both of which reduce the rate of absorption. During waterlogging conditions, there is total check on the water-absorption which is an example of physiological dryness.

Ascent of Sap

Ascent of sap is the translocation of water and inorganic solutes. Ascent of sap means-

i) movement of water and inorganic solutes.

ii) from root to the leaves.

iii) through xylem vessels.

iv) against the force of gravity.

v) and water column remains in a state of tension.

★ Ringing or Girdling experiment by Malpighi confirmed the ascent of sap through **xylem**.

★ Mass Flow or Pressure Flow theory for the movement of food was given by Munch.

Mechanism of Ascent of Sap:

To explain the mechanism of ascent of sap, various theories are put forwarded which are classified under 3 headings :-

(A) Vital Theories :

i) Relay or clambering Pump Theory : This theory was put forwarded by Godlewski (1884) to explain ascent of sap. According to this theory, "Rhythmic change in the osmotic pressure of the living cells of xylem parenchyma and medullary rays bring about a pumping action of water in an upward direction."

Relay pump theory was contradicted by Strasburger (1893). He proved that ascent of sap was independent of living cells because water continued to be transported above even after the killing of living cells by poison (i.e. picric acid) or high temperature.

ii) Pulsation Theory : by Sir J.C. Bose (1923), experiment on *Demodium gyrans* (Indian telegraph plant, Family-Leguminosae) According to Sir J.C. Bose, "Living cells of the inner most layer of the cortex, just outside the endodermis are in a state of rhythmic pulsations which cause the pumping of water for cell to cell in an upward direction."

Benedict (1927) found that the actual rate of ascent of sap was 8000 to 30000 times as rapid as would be possible according to the Bose theory.

(B) Root Pressure Theory :

'Root Pressure' was coined by **Stephan Hales** (**Father of plant Physiology**). The hydrostatic pressure developed due to the accumulation of water absorbed by the roots is called root pressure. Root pressure is measured by **manometer**.

But Root pressure is not sufficient to drive water to a distance of 400 ft. in the trunks of tall trees.

(C) Physical Theories :

All these theories consider the dead cells of plant to be responsible for ascent of sap.

i) Boehm's theory (1809) : According to it, the ascent of sap is partly due to the phenomena of capillarity of the trachea and partly due to the atmospheric pressure.

   The highest column of water attained by capillary forces is 4 ft. and by atmospheric pressure is 34 ft. only.

ii) Jamin's chain theory : Air and water are alternately arranged inside the plant. When air expands, it moves up carying along with it the water column present above it.

iii) Imbibition Theory : According to Sachs (1878), Imbibition activity of cell walls of xylem is responsible for ascent of sap.

iv) Cohesion and Adhesion theory or Transpiration Pull theory: This theory was given by **Dixon & Jolly** (1894) and Askenasy (1895). This theory is most accepted theory. There are three features of this theory :

   a) Strong cohesive force or tensile strength of water.
   b) Continuity of water column in the plant.
   c) Transpiration pull or tension on the unbroken water column.

Loss of water

The loss of water from the living tissues of plants takes place either in vapour form (i.e. transpiration) or in liquid form (i.e. Guttation, Bleeding).

Transpiration

The loss of water in the form of vapour from the living aerial parts of the plant is known as transpiration. The principal organ

of transpiration is leaf. Transpiration may be foliar or lenticular. Again foliar transpiration is of two types viz. stomatal (through stomata) and cuticular (through cuticle).

★ Dry cobalt chloride ($CoCl_2$) is deep blue in colour but when comes in contact with water, it turns into red colour.

Transpiration

- Foliar through leaves
  - Stomatal through stomata (Most of the transpiration is stomatal)
  - Cuticular through cuticle
- Lenticular through lenticels (Lenticels are the pores in the bark of fruits and woody stems)

Difference between Transpiration & Evaporation

	Transpiration	Evaporation
1)	It is a vital & Physiological phenomenon.	1) It is simply physical phenomenon.
2)	The loss of water occurs in the form of vapour from the living cells.	2) It occurs in the form of vapour from the non-living cells.
3)	It is regulated by the guard cells.	3) There is no such regulation.
4)	It prevents the dryness of the cell surface.	4) Evaporation results in the dryness.
5)	There are several mechanism & forces involved in it.	5) There is no such mechanism & forces involved.

Stomata :

i) Stomata are specialised epidermal cells which are distributed all over leaf surface but in case of terrestrial plants, mainly on lower surface of leaves. Therefore approximately 97% of transpiration takes place from the lower surface in such plants.

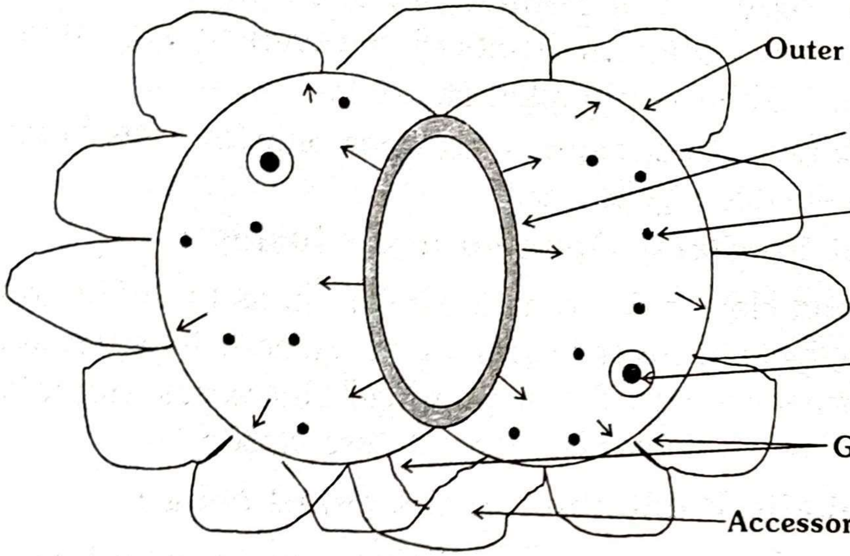


Fig. : Single Stoma

ii) Each stoma (open) has two kidney (or bean) shaped guard cells.

iii) Inner wall of guard cell is thick and outer wall is thin.

iv) Guard cells are surrounded by epidermal or subsidiary or accessory cells.

Classification of Stomata :

According to the distribution of stomata, plants are of five categories:

a) **Apple and Mulbery type :** In such plants, stomata are present on **under surface only**.

b) **Potato type :** More stomata on the lower (or under) surface than on upper surface.

c) **Oat type :** Stomata are equally distributed on both surfaces.

d) **Water Lily type :** Stomata **only** on upper surface.

e) **Potamogeton type :** In such plants stomata are either absent or functionless. Such plants are most of the submerged aquatic plants.

On the basis of daily movement of stomata, Loftfield classified it into three main groups.

1) **Alfalfa type** : Such stomata are open throughout the day and night and are found mostly in thin leaved mesophytes e.g. pea, bean, radish, mustard, vitis etc.

2) **Potato type** : Such stomata are open throughout day and night except for a few hours in the evening. e.g. onion, plantain, cabbage, pumpkin etc.

3) **Barley type** : Such stomata are open only for a few hours during the day e.g. cereals.

Mechanism of Stomatal Opening and Closing :

Opening and closing of stomata are due to its turgidity and flaccidity respectively. It means stomatal movement is governed by turgor movement. When T.P. of guard cells increases, stomata are opened and when decreases, stomata are closed.

[1] Photosynthetic Production in the guard cells :

According to Von Mohl (1856) : Chloroplasts of guard cells synthesize osmotically active substances in the day which increases their osmotic pressure and thus endosmosis. This ultimately leads to stomatal opening and vice versa in the night.

In day :-

i) Conc. of sugar in guard cells increases.
ii) DPD of guard cells increases.
iii) Water enters into guard cells by osmosis.
iv) TP of guard cells increases.
v) Stomata open.

In night, the process is reverse.

This proposition is not acceptable due to

a) Increasing the CO_2 conc. around leaf in bright light causes partial closure of stomata.
b) Chloroplasts of guard cells are either totaly incapable of photosynthesis or can have only feable photosynthesis.

[2] The starch = Sugar hypothesis :

Lloyd (1908) observed that the amount of starch in guard cells increases at night but decreases in day. It means turgidity of guard cells is governed by change in O.P. caused by interconversion of starch and sugar. Scarth (1932) supported the Sayre's hypothesis of starch = sugar interconversion. Sayre thought that the removal of CO_2 by photosynthesis during the light period caused increase in the p^H resulting in the conversion of starch into sugar. This interconversion is catalysed by phosphorylase.

$$\text{Starch} + n\,(\text{inorganic phosphate}) \xrightarrow{\text{Phosphorylase}} n\,(\text{Glucose}-1-PO_4)$$

But in 1964 Steward said that O.P. of guard cells would not be affected appreciably unless glucose–1–PO_4 was further converted to glucose and inorganic phosphate.

$$n(\text{Glucose}-1-PO_4) \xrightarrow{\text{Phosphotase}} \text{Glucose} + PO_4^{=}$$

Illuminated guard cells	**Dark guard cells**
i) Respiratory CO_2 of intercellular spaces is used up by mesophylls in photosynthesis.	i) Accumulates in spaces
ii) p^H of guard cells rises	ii) Falls
iii) The decrease in acidity favours hydrolysis of starch into sugar	iii) The increase in acidity favours sugar → starch
iv) O.P. cell sap of guard cells increases.	iv) Decreases
v) Water enters into guard cells and T.P. and volume increase.	v) Water leaves the guard cells and T.P. and volume decrease.

Drawback :

i) How does the change in CO_2 raise the p^H from 4.5 to 7.0.

ii) Either at the time of opening of stomata or disappearing of starch, sugar is never seen in guard cells. Starch is always changed into organic acid.

iii) In monocot, starch is not formed at all in guard cells.

[3] Active K^+ transport mechanism :

According to Immamura (1943), Yamashita (1952), Fischer and Hsiao (1968) there is a direct correlation between stomatal movements and K^+ concentration of guard cells. K.Raschke (1975) propounded that any of the following processes can initiate stomatal opening :-

i) disappearance of starch from the guard cells;
ii) production of organic acids, particularly malic acid.
iii) excretion of H^+ from guard cells;
iv) uptake of K^+ into the vacuoles of the guard cells;
v) uptake of Cl^- into the vacuoles.

According to Raschke, the excretion of H^+ ion from the guard cells is of primary importance in the stomatal opening. The H^+ ions are to be availed by dissociation of organic acids for exchanging K^+ ions.

Abscisic acid (ABA) blocks the active excretion of H^+ ions from guard cells and thus results in the stomatal closure.

[4] Proton transport concept: It deals with the matter under two heads viz. photoactive opening and scotoactive opening:

a) Photoactive opening : 'The proton transport concept of photoactive stomatal opening' was proposed by Levitt (1974). Actually it is a synthetic theory in which good points of Scarth's classical pH theory and active K^+ transport theory.

b) Scotoactive opening : This theory was proposed by Pallas (1969) and Ehrler (1972). This theory deals with the opening mechanism of stomata during night especially in succulent plants. In succulent plants stomata open during night. In such plants initially stomata close when darkness sets in. It results in O_2 deficiency and is more pronounced in thicker leaves where oxygen is utilised in respiration. This decreases the mitochondrial activity and gives the way to anaerobic respiration. The mitochondrial induced proton transport to cytoplasm is stopped and the resultant acidification of cytoplasm is removed. This raises the p^H of cytoplasm and larger amount of PEP (Phosphoenol Pyruvic Acid) is converted to $R(COOH)_2$ (i.e. organic acid) by PEPC (Phosphoenol Pyruvate Carboxylase Enzyme). It is followed by K^+ absorption. The remaining steps are same to those of photoactive opening.

★ Rate of transpiration is determined by Potometer i.e. **Farmer's Potometer** and Ganong's Potometer.

★ Stomatal opening is measured by Knight's **porometer**.

Guttation

1) The exudation of sap (water) through hydathode (structure present at the tips of veins of leaves) is called guttation.
2) The cause of guttation is root pressure (positive hydrostatic pressure developed in the xylem ducts of the root system.)
3) Necessary condition for guttation : -
   i) Increased absorption of water and decreased transpiration.
   ii) Warm soil & humid or cool atmosphere.
   iii) Warm day and cool night (such condition is available in winter season).
4) Guttation normally occurs at night.
5) Accumulation of salts at leaf tip or leaf margin of some plants during winter is due to guttation.

Hydathode : It is a specialised epidermal cell found at leaf tip or leaf margin i.e. end of veins and veinlets. The group of parenchyma beneath hydathode is known as epithem.

Bleeding

1) The loss of sap (water) from the injured parts of the plant is called bleeding.
2) The cause of bleeding is root pressure.

Difference between Transpiration & Guttation

Transpiration	Guttation
1) It usually occurs in day time	1) It occurs during night.
2) The loss of water occurs in the form of vapour	2) Here occurs in the form of liquid.
3) It occurs through stomata, leticels & cuticle.	3) It occurs through hydath- odes.
4) It is regulated & controlled by stomatal activities.	4) It is regulated by the root pressure and the climatic condition.
5) The after affect of transpiration is cooling the leaf surface.	5) There is no such effect.
6) The transpiring water is pure.	6) Guttation water contains dissolved salts & minerals.

*

11

6 Photosynthesis

Introduction :

1) About 90% of the world's photosynthesis is carried out by marine and fresh water algae.

2) From Aristotles's time to 17th century it was generally believed that plant and animal debris of the soil was the source of plant nutrition. [A]

★

3) According to Van Helmont in early 17th century, it was water and soil which contributed to the plant growth.

4) Stephan Hales (1727) : Green plants may get part of their nourishment through their leaves and sunlight may have to do something with it.

5) Priestley (1772) : Idea of gas exchange taking place in photosynthesis.

6) **Ingenhouz** (Austria, 1779) : Plants purify the air only in the presence of light. Only the green parts of the plant produce the purifiying agent (O_2) while non-green tissue contaminate the air. Thus Ingenhouz recognised **the participation of chlorophyll and light** in the photosynthetic process.

7) Jean Senebier (1800) : Oxygen, liberated from the plants in this process, comes directly from CO_2 which was absorbed by plants.

   Red wavelengths of light is the most effective in this process.

8) de Saussure (1840) : Confirmed the finding of Ingenhouz regarding the gas exchange one in light and other in darkness (respiration). He also discovered that water was also utilised in the process.

9) Dutrochet (1837) : Green part of the plant is essential for photosynthesis.

10) Liebig (1840) : The sole source of 'C' in plants was CO_2 of the air.
11) Robert Mayer : Law of conservation of Energy (1845) and idea of organic synthesis and energy transformation (1848).
12) Sachs (1887) : Green Chloroplast, were the organs where CO_2 was used up and O_2 was liberated. And starch was the first visible product of photosynthesis.
13) Moll's half leaf experiment showed that CO_2 was necessary for photosynthesis.

Photosynthetic Pigments

[A] Chlorophyll Pigments :

★ Chlorophylls occur **mostly in the grana** and are associated with the thylacoid membrane.

★ At least 7 types of chlorophylls are known viz chl a, b, c, d, e, bacteriochlorophyll and bacterioviridin.

★ All chlorophyll (Chl a & Chl. b) molecules contain a tetrapyrrole skelton formed into ring with 'Mg' at the centre. Thus it has five atoms i.e. 4 carbon and one nitrogen. The base unit of the chlorophyll molecule is a porphyrin ring system made up of 4 simple pyrrole nuclei (tetrapyrrole) joined by carbon linkages. The centre of the porphyrine ring is occupied by a **single atom** (non-ionic) of **Magnesium (Mg)**. Only chl.a & chl.b contain Magnesium.

★ Chl. a and chl. b are the most abundant ones found in all autotrophic plants except pigmented bacteria. Other chlorophylls (viz chl. c, chl. d, chl. e) are found only in algae and in combination with chl. a.

★ Precursor of chlorophyll is protochlorophyll but according to recent view the immediate precursor is chlorophyllide.
Protochlorophyllide → chlorophyllide → chl. a → chl. b

★ In fresh green leaves, the proportions of photosynthetic pigments are as follows:

S.No.	Name of pigment	Proportion	Remarks
1.	Chlorophyll a	2 parts	Green
2.	Chlorophyll b	2/3rd of one part	pigment
3.	Carotene	1/6th of one part	
4.	Xanthophyll	1/3rd of one part per 1000 parts	yellow pigment

★ **Difference between chl a & chl. b.**

S.No. Chl. a	Chl. b
1) It is a blue-green microcrystalline solid	1) It is a green-black microcystalline solid.
2). Empirical formula of chl a is $C_{55}H_{72}O_5N_4Mg$	2) Empirical formula of chl.b is $C_{55}H_{70}O_6N_4Mg$
3) It gives a blue-green solution in ethyl alcohol, etc.	3) It gives yellow-green solution in ethyl alcohol.
4) Its occurence is universal in green plants.	4) Its occurance is in higher plants and green algae but absent in blue-green, brown and red algae.
5) It possesses a $-CH_3$ group (methyl group) attached to carbon no. - 3.	5) It possesses – CHO (aldehyde) group in place of $-CH_3$ group.
6) Maximum absorption occurs at 449 mμ in blue end and 2nd peak at 660 mμ in red end of spectrum.	6) Maximum absorption occurs at 453 mμ in blue end and 2nd max. at 642 mμ in red end of spectrum.
7) Light absorbed by chl a is utilised by itself in photosynthesis.	7) Light absorbed by chl. b or its substitutes (chl. c and chl. d) is passed on to chl. a.

[B] Carotenoid Pigments :

- ★ Carotene and Xanthophyll are together called carotenoids.
- ★ These are fat soluble yellow pigments.
- ★ Carotenoids are located in chloroplast and chromoplast.
- ★ Yellow colour of etiolated and variegated leaves is due to carotenoids.

- ★ Such pigments are composed of two 6–membered rings with a hydrocarbon chain stretched between them.
- ★ Light energy absorbed by carotenoids is shunted to chl. a and light absorption results in fluorescence of chlorophyll.
- ★ Strong absorption takes place in the blue violet and ultraviolet end of spectrum with almost no absorption in the red end.

Carotene :

- ★ Its colour is Orange-yellow having empirical formula $C_{40}H_{56}$ (i.e. exclusively of C & H.)
- ★ It is abundant in roots of carrot hence the name carotene.
- ★ It is insoluble in water.
- ★ Its most common form is β-carotene. β-carotene is the precursor of vit. A. Other forms of carotene are α-carotene, γ-carotene.
- ★ It is quickly oxidised in air and hence the rapid change of colour takes place in the scaped carrot.

Xanthophylls/Carotenols :

- ★ It is more abundant than carotenes.
- ★ It occur in many isomeric forms having colour yellow to brown.
- ★ Empirical formula is $C_{40}H_{56}O_2$
- ★ It is also called carotenol.
- ★ The commonent form is Luteol (lutein) followed by violaxanthal (violaxanthin).
- ★ The principal yellow pigment of maize is zeaxanthin.

[C] Phycobilin pigments

- ★ Phycobilins are found in **blue-green** and **red algae**.
- ★ It has tetrapyrrole rings but in straight chain.
- ★ Light absorbed by phycobilins is transferred to chl. a where is used in photosynthesis.
- ★ It contains no magnesium (Mg.)
- ★ Red pigment is called phyco-erythrin and blue pigment is phycocyanin found in red algae and blue-green algae respectively.

★ It is soluble in hot water while chlorophylls and carotenoids are soluble in organic solvent.

★ It masks the green colour like anthocyanin.

[**Anthocyanin** : is a purple pigment, soluble in water hence it occurs in solution in the water of the cells means it is actually dissolved in the cell sap and not in cytoplasm; does not take part in photosynthesis; present in sugarbeet].

Photosynthesis/CO_2 assimilation/Food Production

It has two phases viz. light phase and a dark phase.

★ Reaction of the light phase is light sensitive hence called photochemical reaction.

★ The reactions of the dark phase are temperature sensitive and don't require light. These are purely chemical reaction and called **Blackman reactions** on the name of F.F. Blackman who first demonstrated its existence.

★ These two steps are

$$\xrightarrow[\text{Photochemical reaction}]{\text{Step I}} \xrightarrow[\text{Chemical reaction}]{\text{Step II}} \text{Photosynthetic Product}$$

★ Reactants : $CO_2 + H_2O$

ii) Requirement : Energy (light) + Catalyst (pigments)

iii) Products : Food (carbohydrate) + O_2

★ Ancient view :

$6\,CO_2$ + $6H_2O$ ===== $C_6H_{12}O_6$ + $6O_2$

(12 oxygen atoms) (6 oxygen atoms) Product (12 oxygen atoms)

Source of O_2 = CO_2

★ Modern View :

Source of O_2 = H_2O

Evidences in support of source of O_2 is H_2O, are given by following scientists:

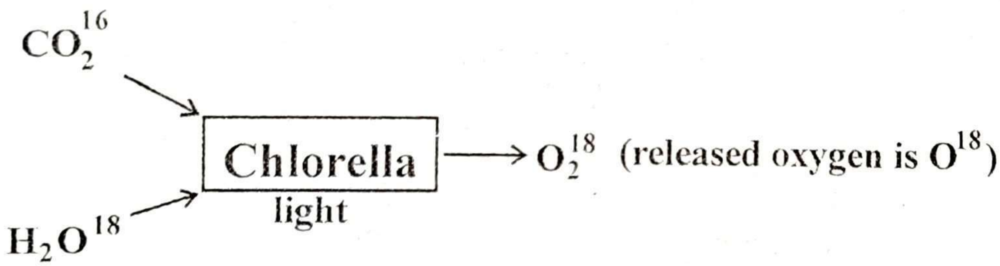
1) Von Niel : Experiment on bacteria i.e. purple sulphure bacteria. These bacteria are autotrophic and photosynthetic. (Normally bacteria are hetero-trophs)

$$CO_2 + \boxed{H_2}\boxed{S} \xrightarrow[\text{pigment}]{\text{light}} C_6H_{12}O_6 + [S]$$

Similarly in higher plants,

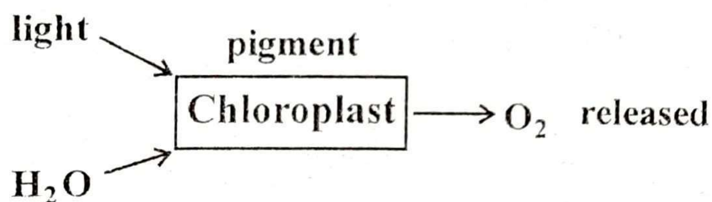
$$CO_2 + \boxed{H_2}\boxed{O} \xrightarrow[\text{pigment}]{\text{light}} C_6H_{12}O_6 + [O]$$

2) Ruben : Experiment by Ruben is more authentic work. His experiment was on Alga (i.e. chlorella) through isotopic studies (O^{16} and O^{18})



Conclusion : Source of Oxygen is water

3) Hill : Experiment on cell free or isolated chloroplast

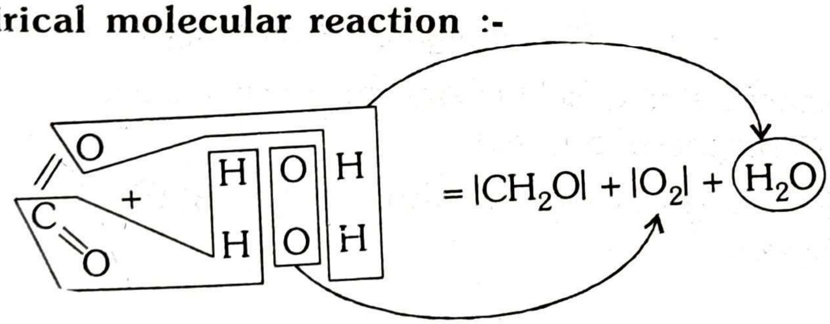


Here CO_2 is not supplied to isolated chloroplast although O_2 is released. This reaction is called Hill's reaction.

On the basis of the above evidences, the revised reaction of photosynthesis is-

$$6CO_2 + \underset{\text{reactant}}{12H_2O} \xrightarrow[\text{chlorophyll}]{\text{686 KCal. of radiant energy}} C_6H_{12}O_6 + 6O_2 + \underset{\text{product}}{6H_2O}$$

Empirical molecular reaction :-



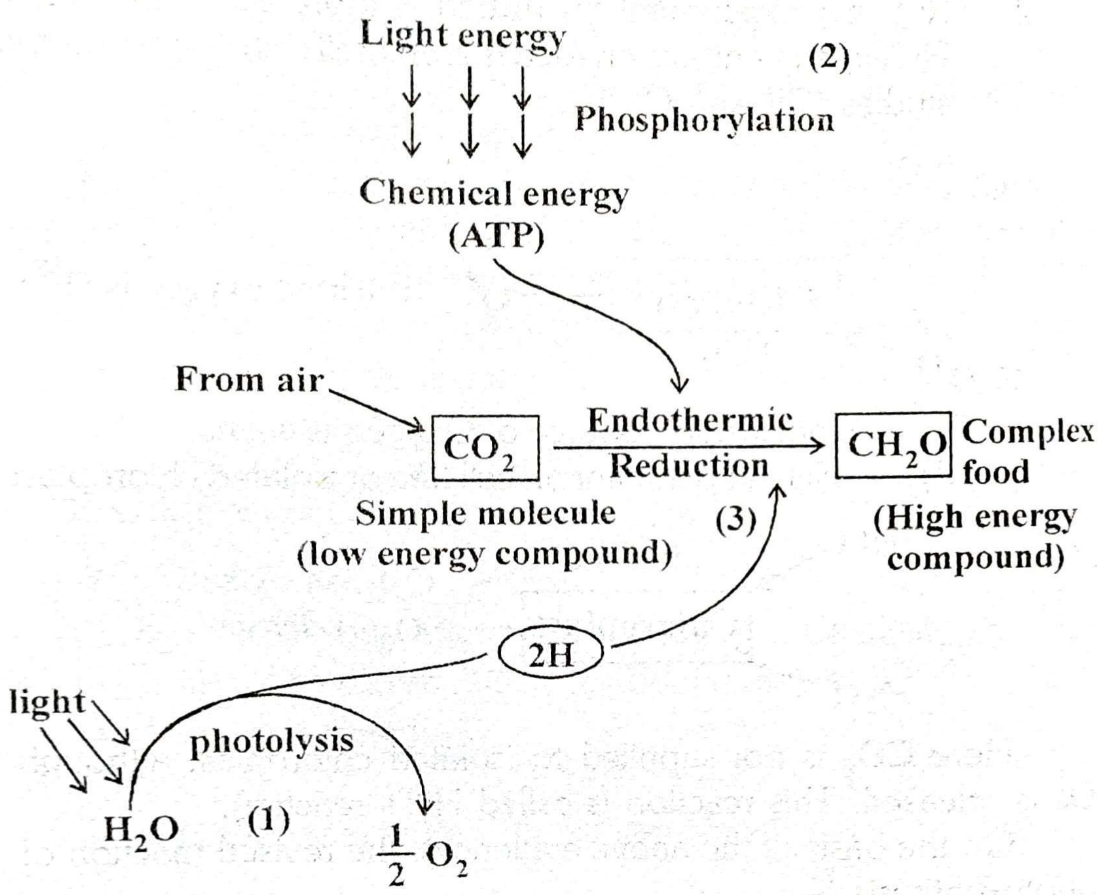
three inferences are drawn from the empirical molecular formula-

a) Breakdown of water molecule to release of O_2

b) 50% Hydrogen from water combines with $C = O$ of CO_2 to produce food.

c) Remaining 50%H of H_2O combines with [O] of CO_2 to produce water.

Division of labour : Light and Dark reaction :



$$ADP + Pi \xrightarrow{Light} ATP$$

Pi is Inorganic Phosphate

The conversion of light energy into chemical energy i.e. ATP is called *Photophosphorylation*.

ATP = Adenosine triphosphate; ADP=Adenosine Diphosphate

The breakdown of water molecule (H_2O) into hydrogen and oxygen by light energy is called *Photolysis* of water. (Photo means light and lysis means to break).

Origin of Food : Three major reactions are

1) Photolysis of water : For hydrogen (2H)] Both light
2) Photophosphorylation : For ATP] dependent
3) CO_2 - reduction : For carbohydrate - Dark dependent.

Hence there are two phases viz. Light phase and Dark phase.

Light Reactions

Evidences :

a) Hill's work with isolated chloroplasts : Hill (1937, 1939) and Scarisbrick (1940).

Light →

$\boxed{\text{Isolated Chloroplast}}$ + H_2O ⟶ O_2 released

+

If Oxidant (H-acceptor) ⟶ reduced oxidant
(called Hill reagent) by chloroplasts

If Oxidant (i.e. H-acceptor) is present with isolated chloroplast, oxidant is reduced by chloroplast in presence of light. This reaction is called **Hill reaction** and oxidant is called Hill reagent. The common Hill reagent is **Ferricyanide** and **Benzoquinone**.

Robert Hill discovered firstly that chlorplasts use cytochromes for photosynthesis just as mitochondria use them for respiration.

Warburg (in early 1940's) : Cl^- has stimulating effect on the Hill reaction probably by facilitating the release of O_2 from OH^- ions.

b) D.Arnon's work with isolated chloroplasts :

i) Arnon (1951) : H-released by splitting of H_2O molecule was accepted by coenzyme II (i.e. TPN^+, now called $NADP^{++}$).
(NADP : Nicotinamide Adenine Dinucleotide Phosphate)

ii) Arnon (1954) : In addition to carrying out the Hill reaction, The isolated chloroplasts could also synthesize ATP in the light.

ADP+Pi (inorganic phosphate $\xrightarrow{\text{Light energy}}$ ATP

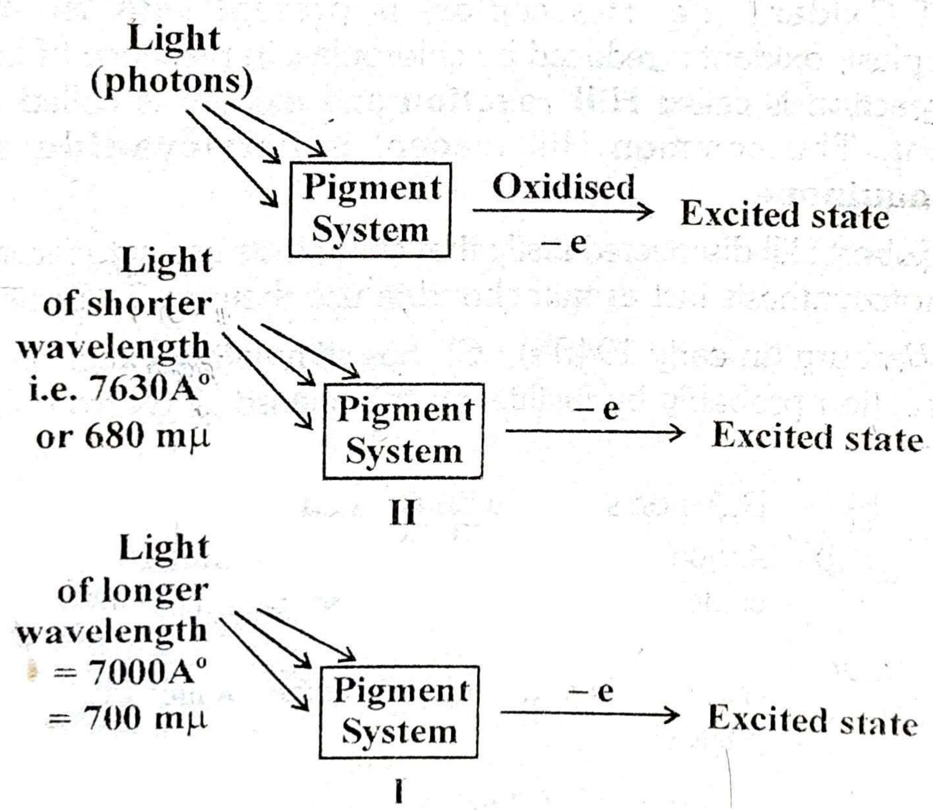
iii) Arnon (1959) : Isolated chloroplast also reduced CO_2 in presence of light and this would result in the synthesis of carbohydrate. The conversion of CO_2 into sugar (dark reaction) actually took place in the stroma (the chlorophyll-free portion of the chloroplast) and the Hill reaction (Light reaction) took place properly in the grana.

★ The site of light reaction is grana and dependent on pigment.

For better perception, let's divide the light reaction into four (4) steps:

1st Step : Photo-excitation of pigment electrons. The effect of photo-excitation is oxidation of pigments. Emerson's work discovered the two pigment systems:

$1 m\mu = 1$ milli micron $= 10^{-3} \times 10^{-6}$ metre $= 10^{-9}$ m
1 nm = 1 nano metre $= 10^{-9}$ m
1 A^0 = 1 Angstrom $= 10^{-10}$ m



It means pigment system works on quality of light i.e. blue and Red.

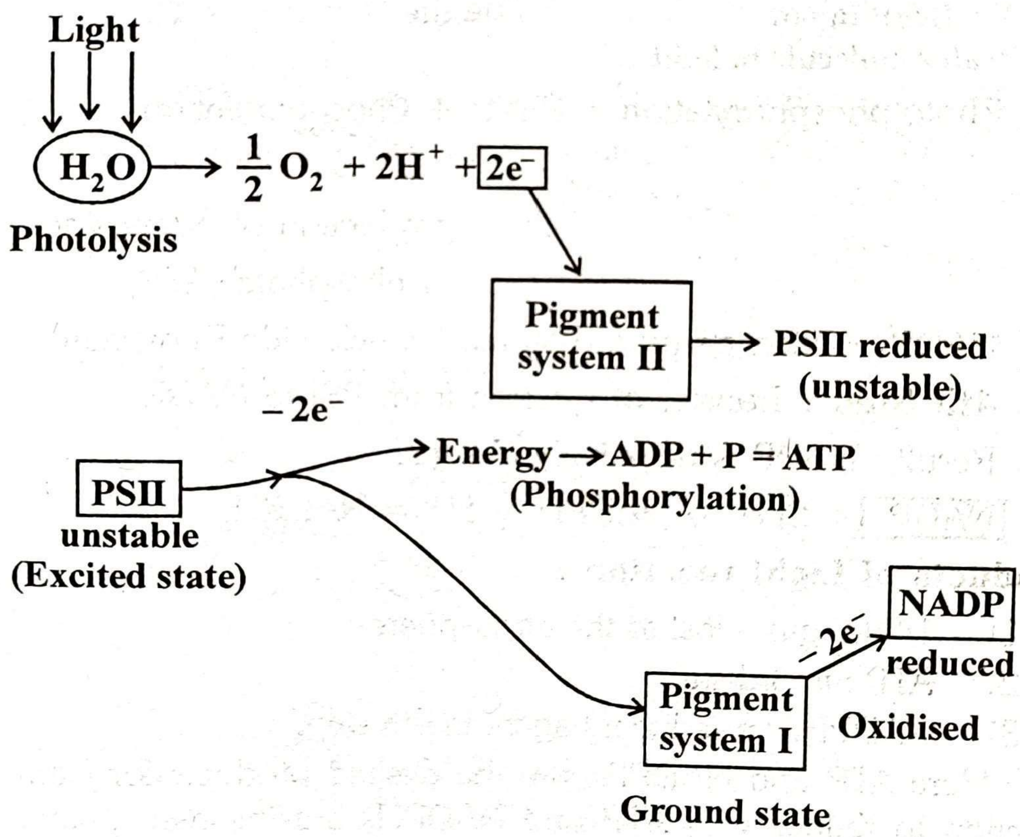
2nd Step : Photolysis of water

$\downarrow$

release of electron

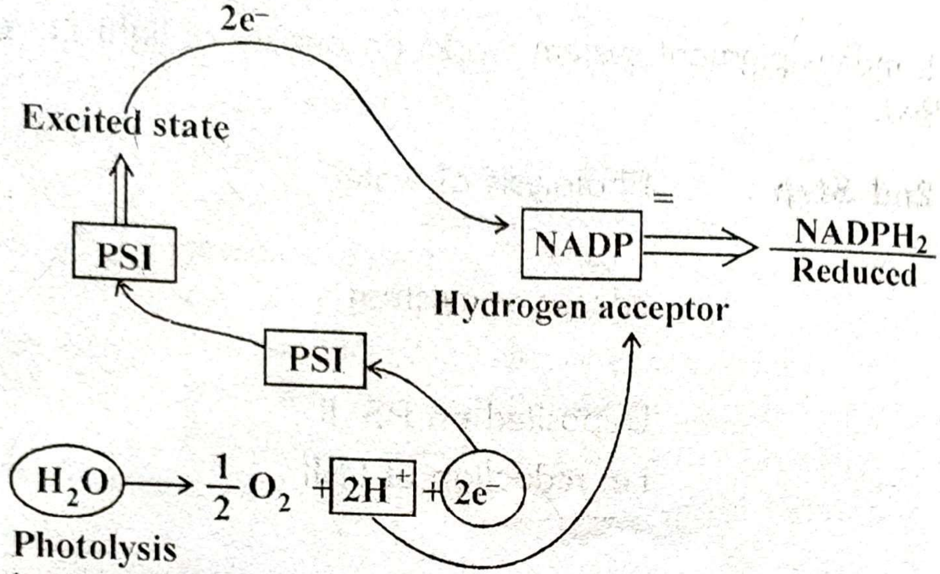
$\downarrow$

Deposited on P.S. II
i.e. reduction of PSII



3rd Step : Return of Excited electron from PSII to PSI in ground state.

Effect :
- Direct : Reduction of PSI
- Indirect : Photophosphorylation
  i.e. production of ATP by the involvement of photons (light)
  i.e. Energy stored in the form of ATP



Photolysis
i.e. Breaking of
water molecule in light

Photo phosphorylation = Photo + Phosphorylation

$\downarrow$ light; $\downarrow$ production of Adenosine tri phosphate (ATP).

NADP = Nicotinamide Adenine Dinucleotide Phosphate.

4th Step : Transfer of electron from PSI to NADP.

Result : NADP is negatively charged

$\boxed{NADP^{=}} + 2H^+ \rightarrow NADPH + H^+ = NADPH_2$

Products of Light reaction :

1) 1/2 O_2 gas – lost to the atmosphere
2) ATP : in 3rd step
3) $NADPH_2$: a reducing agent in 4th step.

Here ATP and $NADPH_2$ are the desired products for Dark reaction to reduce CO_2.ATP and $NADPH_2$ are the assimilatory power because they help in the process of CO_2 assimilation. There are two pathways of the transfer of electron i.e. (a) Non-cyclic and (b) cyclic. Since ATP is released in the both pathways. Thus photo phosphorylation is the name.

(a) Non-cyclic photophosphorylation : It involves both PSI & PSII systems and occurs in green plant.

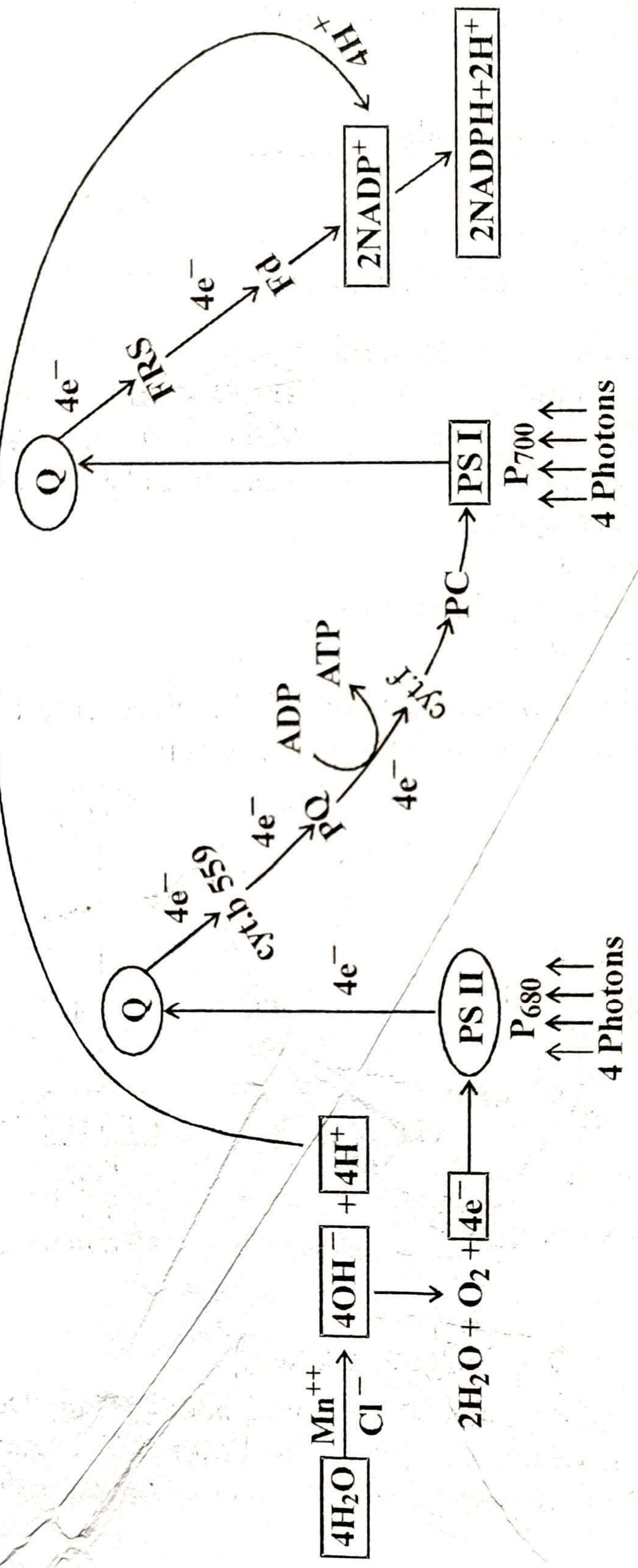


Fig. : Non-cyclic pathway of Electron
i.e. Non-cyclic photophosphorylation

Products : $\frac{1}{2}O_2 + ATP + NADPH_2$

$$ADP + Pi \xrightarrow[\uparrow \text{ energy}]{\text{chemical bonds}} ATP$$

7 – 11 kilo calories

x = unknown compound
Q – Quinone
PQ – Plastoquinone
Cyt – Cytochrome
PC – Plastocyanin
FRS – Ferredoxin Reducing Substance
Fd – Ferredoxin

$4H_2O = 4H^+ + 4OH^-$
$4OH^- = 4OH + 4e^-$
$4OH = 2H_2O + O_2$

(b) Cyclic photophosphorylation : It involves only PSI and wavelength of light greater than 680 nm.

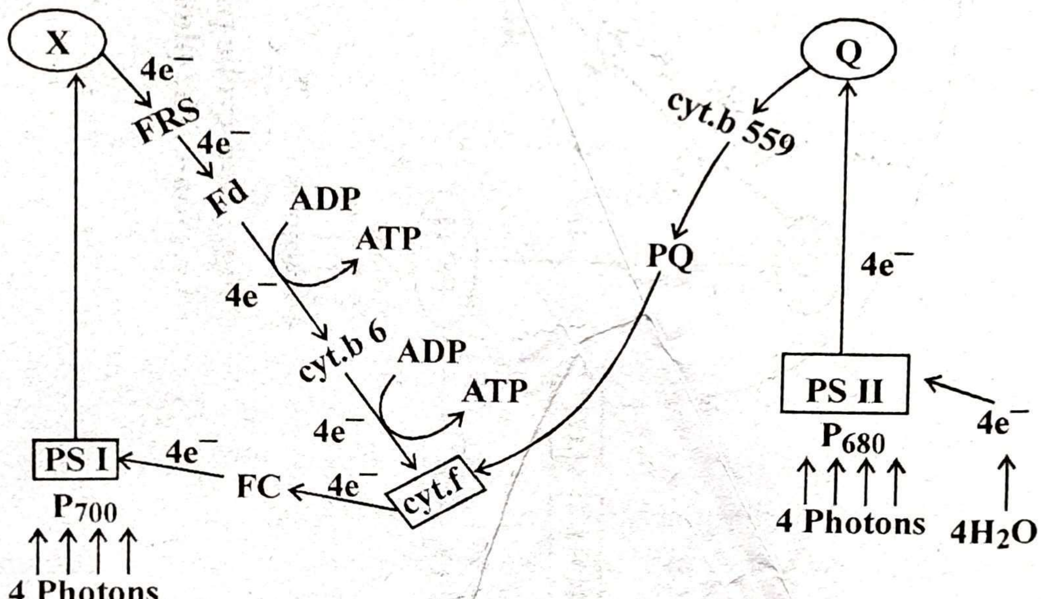


Fig. : Cyclic pathway

when green plant treated by Dichloro Dimethyl Urea (DCMU: a selective poision which inactivates the PSII); ATP production was continued. From this experiment two conclusions were drawn:

1) Alternative pathway is present to produce ATP other than non-cyclic.

2) Alternative pathway was entirely dependent on only PSI.

According to Park & Sane (1971) stromal lamellae has PSI whereas granal lamellae has both PSI & PSII. It means

Stroma ≡ PSI ≡ cyclic photophosphorylation

Grana ≡ PSII ≡ Non-cyclic photophosphorylation.

Difference between Non-cyclic & cyclic photo phosphorylation:

Non-cyclic	**Cyclic**
1) It is dependent on both PSII & PSI	1) Dependent on only PSI
2) Presence of Mixed light i.e. long & short wavelength required.	2) Monochromatic light of longer wavelentgh.
3) ATP is produced when movement of electrons from PSII to PSI	3) ATP production when movement of electron from PSI to PSI
4) Products : $\frac{1}{2}O_2 + ATP + NADPH_2$	4) Product : Only 2 ATP
5) Photolysis of water essential	5) No need of photolysis of water.
6) Water molecule is the source of electron (e^-) which helps the chlorophyll molecule to come to ground state.	6) Electron comes from P_{700}. Water is not the source.
7) The electron (e^-) does not complete the cycle. It starts from PSII and drained off in the carbohydrates produced by CO_2 reduction	7) Electron moves from P_{700} to P_{700} through 2-3 transfer steps to decreasing redox potential

Robert Emerson's work & Red Drop :

Robert emerson found that 8 quanta of light energy would be required for the reduction of one molecule of CO_2 to carbohydrate.

8 quanta of photons (i.e. light energy) = For reduction of 1 molecule of CO_2 to carbohydrate
≡ i.e. Production of 1 molecule of O_2 .

8 quanta ≡ 1 molecule of CO_2 ≡ 1 molecule of O_2
(reduction) (production)

Thus quantum yield or yield per quantum = 1/8 = 12%

The average maximum quantum yield in photosynthesis is 12 percent.

Quantum yield may be defined as the number of O_2– molecule released per light quantum absorbed.

Reduction of 1 molecule of CO_2 ≡ transfer of 4 electrons

8 quanta ≡ 4 electrons-transfer

2 quanta of light = one electrons transfer.

Thus for the movement of one electron through the complete system, 2 photons are needed, one at PSI and one at PSII. For the removal of $4e^-$ from the 4 water molecules, 8 photons are required which generate 1 molecule of O_2; 2 molecules of ATP and $NADPH_2$. In reductive pentose phosphate pathway (PPP), 3 molecules of ATP are required in the assimilation of 1 molecule of CO_2. An additional 2 photons are sufficient to provide an extra ATP making them to the requirement of 10 photons.

According to Emerson & Arnold (1932): 2500 chlorophyll molecules (a photosynthetic unit) collaborated together to evolve one molecule of O_2 and10 quanta of light were needed for that.

Photosynthetic Unit : It is the smallest group of pigment molecules which collaborate together to cause a photochemical act i.e. the absorption and migration of a light quantum to a trapping centre where it brings about the release of an electron.

Photosynthetic unit = 2500 molecules of chlorophyll.

Example : $P_{700} = P_{680}$

Emerson's Effect :

a) **Green Plant** $\Leftarrow$ exposed to monochromatic light i.e. wavelength greater than 680 nm in red zone.

$\Downarrow$ prolonged duration of Red zone

Rate of photosynthesis decreased

i.e. quantum yield decreased

This effect is called $\boxed{\text{Red Drop}}$

Emerson's first effect.

The decrease in the quantum yield or photosynthetic rate after using the monochromatic light i.e. red, for the long duration is called Red Drop.

b) **Plant A** $\longrightarrow$ **X Quantum yield**

↑↑↑↑

Wavelength greater than 680 mμ of light

Plant A $\longrightarrow$ **Y Quantum yield**

↑↑↑↑

Light of the shorter wavelength

Plant A $\longrightarrow$ **Z Quantum yield**

↑↑↑↑

Mixed beam of light Z > X + Y

Emerson found that

The quantum yield produced by the mixed light was greater than the total yield got from the two beams of light used separately.

This enhancement of photosynthetic rate is called Emerson's Enhancement Effect or Emerson's 2nd Effect.

Explanations of Emerson's Effect :

In monochromatic light, only one type of pigment is Functional and hence the decrease in the photosynthesis. If plant is exposed to red light, gradually PSII becomes inactive and non-cyclic pathway stops resulting in the decrease in photosynthetic rate.

Dark Reactions

Dark phase of photosynthesis i.e. CO_2 Fixation.

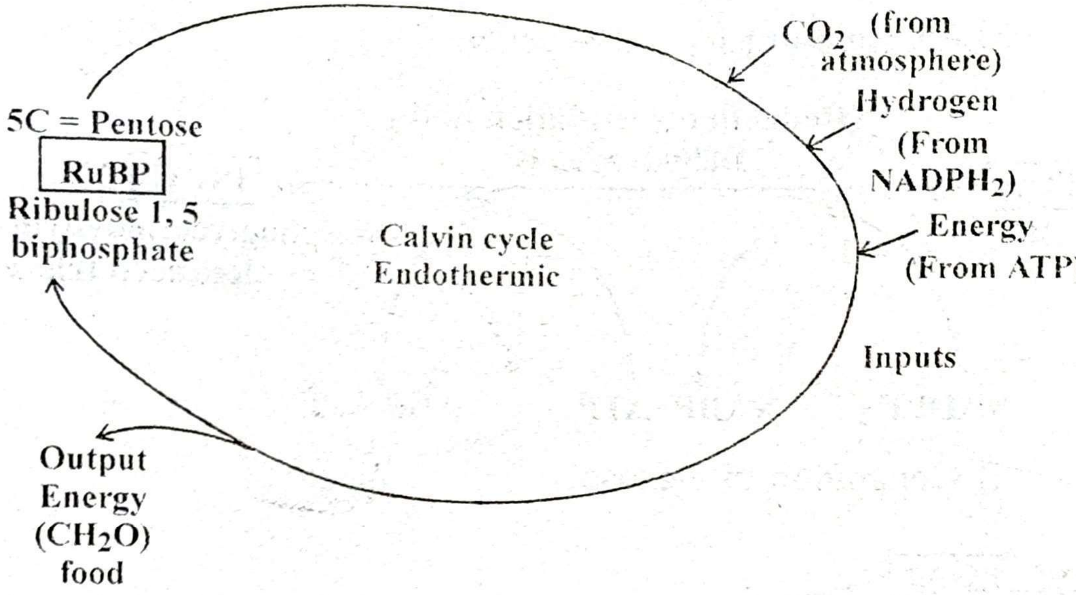
Dark reactions are dependent on Enzymes but light reactions are dependent on pigments. In Dark reaction, CO_2 is reduced to carboydrates with the help of the products of light reaction. i.e. ATP and $NADPH_2$. There are three pathways of dark phase of CO_2 Fixation.

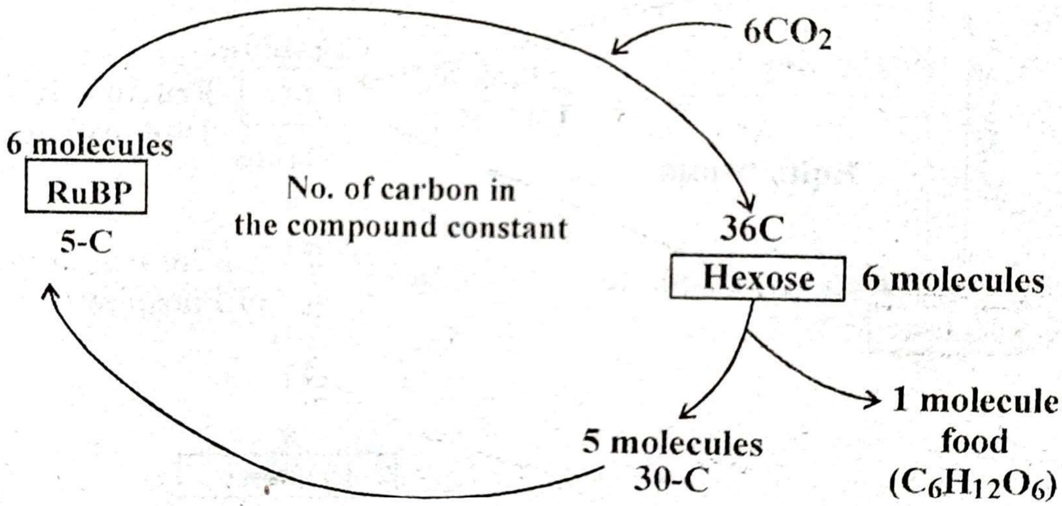
a) Calvin Cycle : C_3 cycle
b) Hatch and Slack cycle : C_4 cycle
c) CAM cycle.

Calvin cycle/C_3-cycle

This cycle is predominantly found in wheat, rice, barley, pulses etc. and such plants are called C_3 plants because in the cavin cycle, first stable product is C-3 compound (i.e. having three no. of carbons in a compound).

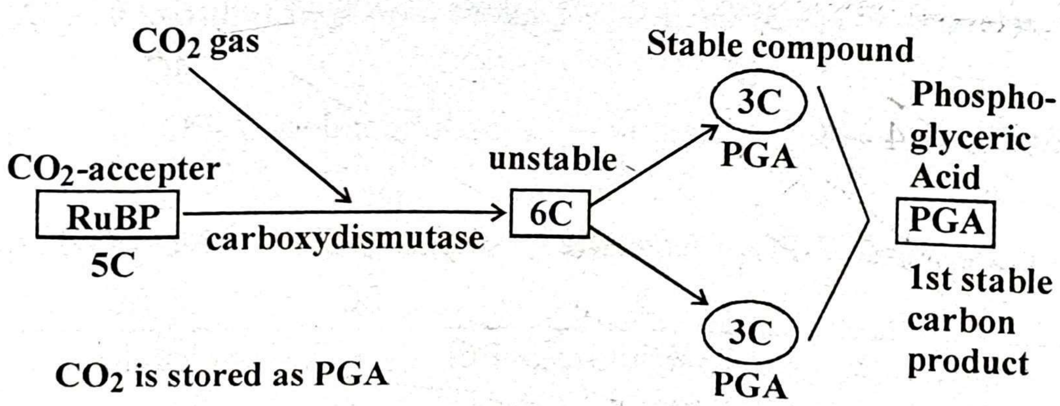
1) 6 molecules of RuBP (Ribulose biphosphate, earlier called RuDP) combine with 6 molecules of CO_2 which produces 6 molecules of carbohydrate (hexose).
2) One out of 6 molecules of Hexoses is consumed as food.
3) Remaining 5 molecules of Hexoses are reconverted to RuBP (6 molecules) and thus completes the cycle.



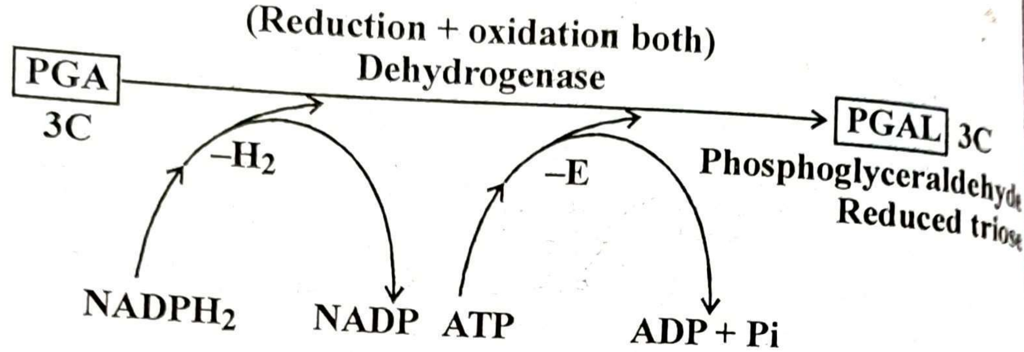


Procution of Hexose :

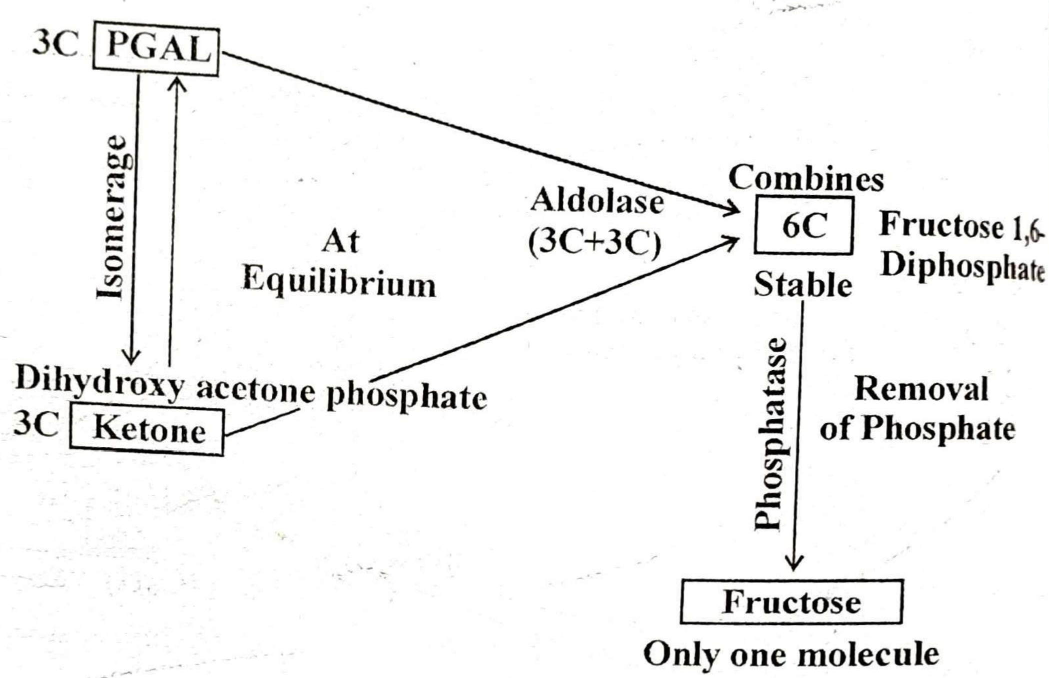
a) Reception of CO_2 :



b) Reception of H_2 :– Reduction



c) Generation of Hexose



Regeneration of RuBP (5C)

6C ⟶ 5C.

Fructose 6–PO_4+3PGAL ⟶ Xylulose 5–PO_4+Erythrose 4 –PO_4
6C 3C 5C 4C

Erythrose 4 –PO_4 + Ketone ⟶ Sedoheptulose 7–PO_4
4C 3C 7C

Sedoheptulose 7–PO_4+Aldehyde ⟶ Xylulose 5–PO_4+Ribose5–PO_4
7C 3C 5C 5C

Products : Xylulose 5–PO_4 ⟶ Two molecules
Ribose 5–PO_4 ⟶ One molecule

Ribose 5–PO_4

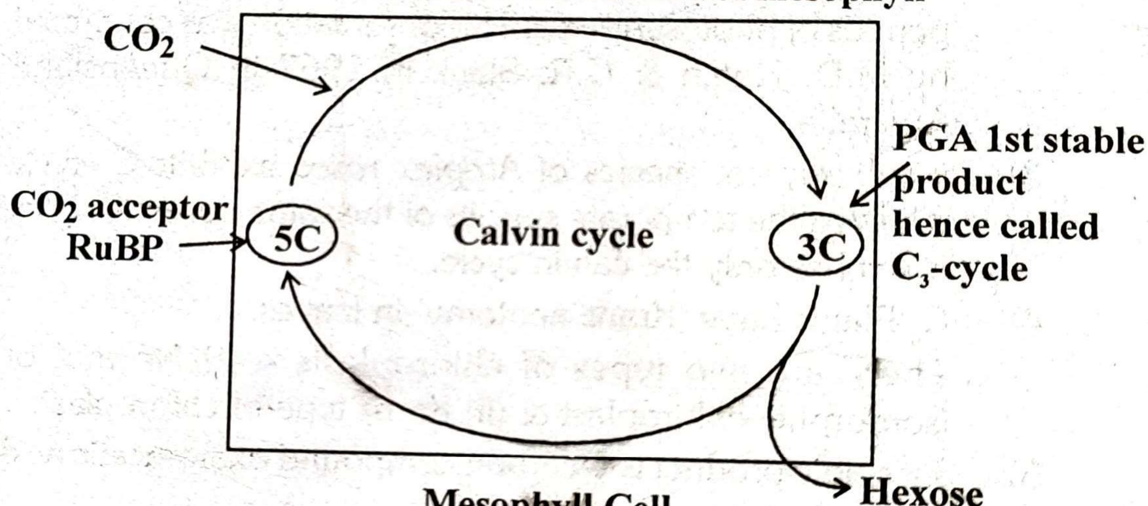
↓ Isomeric modification

Ribulose 5-PO_4 (Ribulose Monophosphate = RuMP)

↓ ATP → ADP

Ribulose 1, 5-biphosphate (RuBP)

Reaction Centre : localised i.e. one cell of mesophyll



Mesophyll Cell

Blackman's Law : Law of Minimum or Law of limiting factor:

a)

Light (x) contant

$\boxed{ATP+NADPH_2}$ = assimilatory power constant

$CO_2 \xrightarrow{\text{reduction}} CH_2O$

say 100 molecules

food

say 5 mg

If light intensity is increased by twice but CO_2 -Concentration is constant, there will be no increase in photosynthetic rate. It means CO_2 acts as a limiting factor because it's concentration is available in minimum quantity.

Inferences :

1) The law is applicable to only those reactions where the rate is governed by multiple factors like photosynthesis.
2) The rate of such reaction is dependent on any one factor at specific time – Limiting factor or governing factor.
3) The limiting factor will be that one which is available in minimum quantity i.e. Law of Minimum.

Hatch & Slack cycle/C_4 cycle

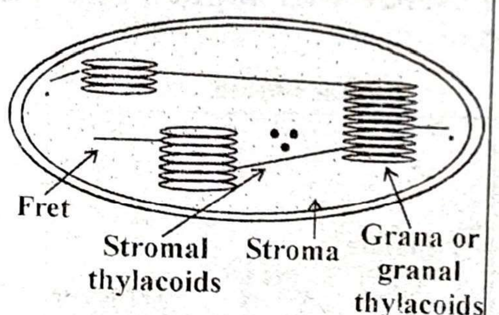
1) It is found in Sugarcane, maize, sorghum, bajra etc. such plants are called C_4-plants.
2) In 1965 Kortschak, Hartt & Burr working with $C^{14}O_2$ on sugarcane leaves found C_4 dicarboxylic acid, malate & aspartate to be the major labelled products in very short periods of photosynthesis. This observation was confirmed by M.D. Hatch & C.R. Slack in 1967 in Queensland Australia.
3) a sub-tropical species of *Atriplex rosea* exhibits C_4-cycle whereas the temperate species of the same genus *Atriplex rosea* has only the calvin cycle.

4) C_4-Plants have 'Kranz anatomy' in leaves.
   There are two types of chloroplasts – (i) Normal or isomorphic chloroplast & (ii) Karnz type of chloroplast.
5) 1st stable product is 4-carbon compound oxalo-acetic acid hence the name C_4-cycle.
6) PEP carboxylase has high affinity for CO_2 and hence C_4 plants are able to absorb CO_2 strongly from a much lower CO_2 -concentration than the C_3-plants. Thereby resulting higher rate of photosynthesis.
7) Most of the bad weeds of the world are C_4-plant.

Normal Chloroplast	'Kranz' type Chloroplast
1) Such chloroplasts are normal & isomorphic having grana,stroma & frets distinctly. Grana are double membraned closed vesicles called thylacoids. The grana contains the chlorophyll a & b in the ratio of 3:1 along	1) Such chloroplast are dimorphic. It is undifferentiated. These chloroplast lack grana and contain starch grains. These are arranged centripetally within the cells of the bundle sheath.Such chloroplasts are very large.

with carotenoids & xanthophyll. The large thylacoids extend to one end to the other end of the chloroplasts called 'stroma thylacoids' whereas the small thylacoids are alternately arranged & fused with the large ones in the granum region only called 'grana thylacoids.'	
2) Stromal thylacoids contain PSI means carry out only cyclic photophosphorylation while granal thylacoids contain both PSI & PSII means carry out both Non-cyclic & cyclic photophosphorylation.	2) Such chloroplast lack PSII and hence are dependent on the chloroplasts of mesophyll for the supply of $NADPH_2$.
3) The chloroplasts in all the green cells of the leaves are alike and found in C_3 & C_4 plants both.	3) Such chloroplasts are found in the bundle-sheath cells of C_4-plant.

4)



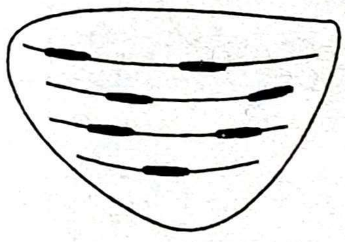


Fig. granal chloroplast

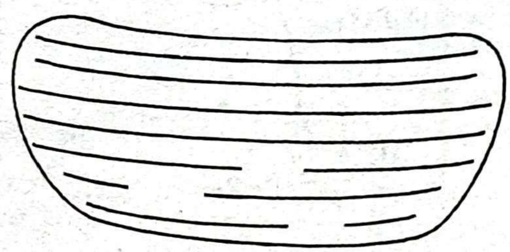
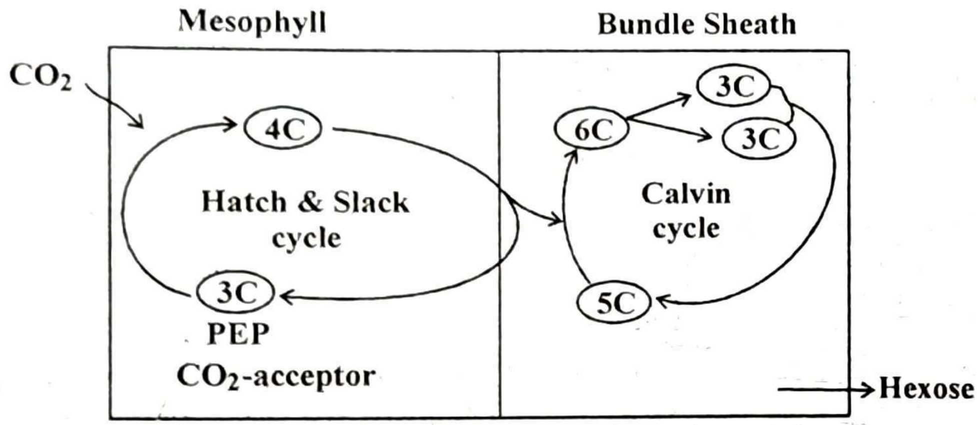


Fig Kranz anatomy (agranal chloroplast)

Reaction centre : Division of labour :



Here CO_2 - acceptor is PEP i.e. phosphoenol pyruvate which is the substitute of RuBP of C_3 plant.

Plasmodesmata is the channel for the transfer of 4C compound from mesophyll to Bundle-sheath.Depending on the process of decarboxylation of C_4-acids within the bundle-sheath, C_4 plant species are divided into three sub-groups viz. NADP-ME type; PCK type & NAD-ME type.

a) **NADP-ME type :** Malate formed within the chloroplast of bundle sheath is decarboxylated via NADP-malic enzyme, hence called NADP-ME type. Here **only chloroplast** is involved.

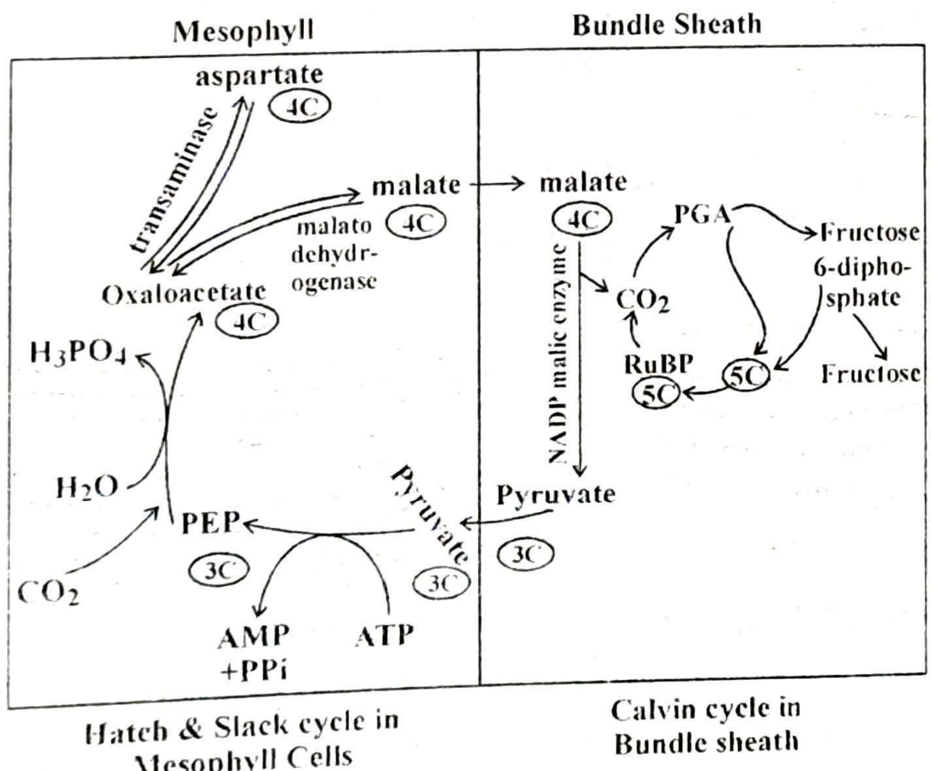
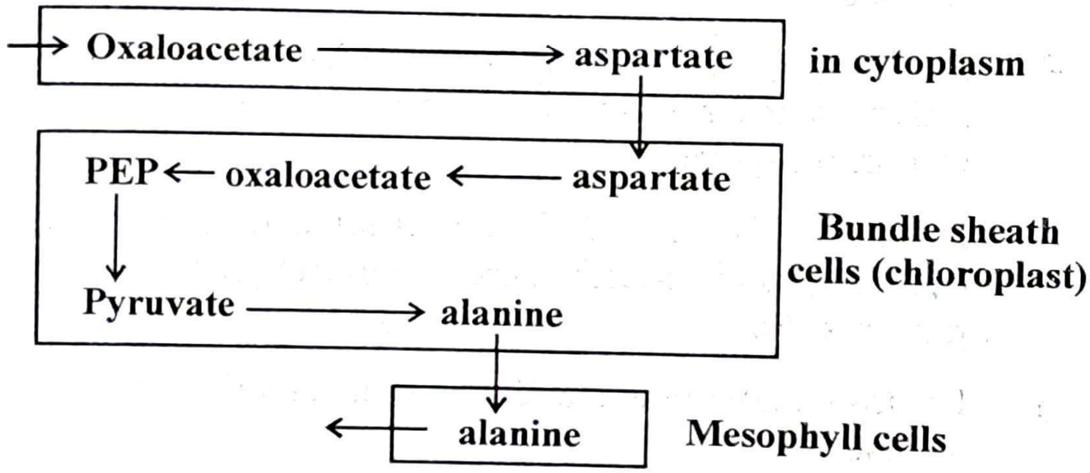
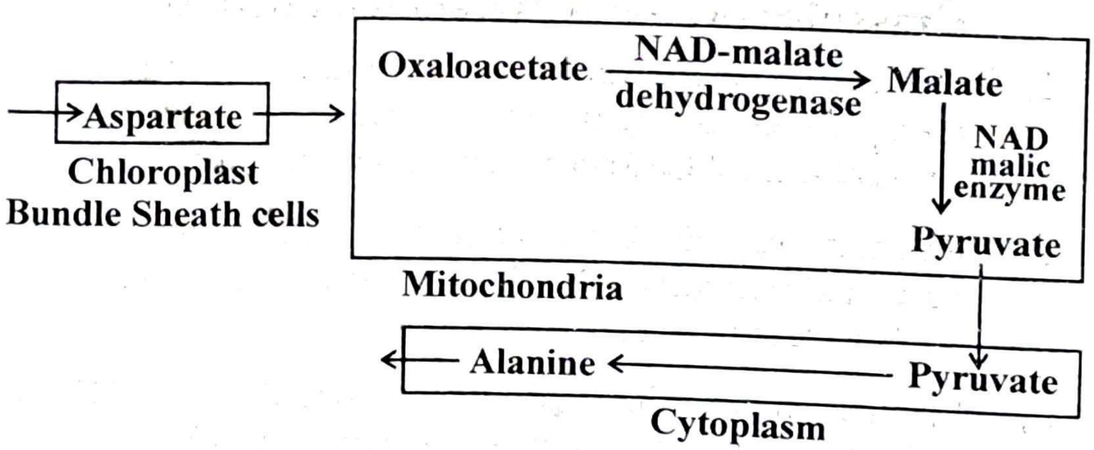


Fig. : NADP-ME type

b) **PCK-type** : Oxaloacetate is converted to aspartate by aspartate aminotransferase within cytoplasm. Then aspartate is transported to Bundle sheath cells. In Bundle sheath, aspartate is converted back to oxalo-acetate and oxaloacetate is decarboxylated to form PEP which yields pyruvate. Pyruvate is converted to Alanine and diffuses into mesophyll cells. It involves **Chloroplast & cytoplasm**.



c) **NAD-ME type** : Like PCK type, aspartate enters into the bundle sheath cells. It diffuses into mito-chondria where it is converted to oxaloacetate and oxaloacetate is reduced to malate which is decarboxylated to pyruvate. Pyruvate diffuses out of mitochondria & enters into cytoplasm where it is converted to alanine. It involves *Mitochondria, Cytoplasm & Chloroplast.*



Physiological Differences in relation to dry matter production between C_3 & C_4 plants:

1) The PEP carboxylase enzyme present in C_4 cycle has a

very strong affinity for CO_2 as compared to RuBP carboxylase. Hence law of Minimum regarding the CO_2 - concentration is not in operation for C_4-plants.

2) PEP carboxylase is not sensitive to O_2 which has a cometitive effect on RuBP carboxylase.

3) C_4 plants lack photo respiration, hence photosynthetic rate is higher.

4) In Mesophyll cells of C_3, Nitrogen (N) & Sulphure (S) reduction occur and so they compete for reducing power with photosynthesis.

5) In mesophyll cells of C_4, N & S-reduction occur but calvin cycle is in Bundle sheath, therefore competition for reducing power is low.

6) Photosynthates made in C_4 plants are readily transported to other parts.

7) High temperature is optimum in C_4 plants for enzyme thereby increasing the photosynthetic turn over rate higher.

8) High light saturation point (in C_4) combing higher electron transport and more generation of reducing power ($NADPH_2$) & ATP.

Crassulacean Acid Metabolism (CAM)

1) Occurence : Certain succulent plants of the family crassulaceae like cactus (cacti); pineapple, Onion, garlic, lili, sisal etc. All CAM-plants have succulent habit.

2) Adaptability : Extreme dessication, such plants posses xerophytic characteristics like reduced leaves, thick cuticle, sunken stomata etc.

3) Special feature : Such plants have also the capability of fixing the CO_2 lost in respiration. Such plants behave like C_4-plants during the night and as C_3-plants during the day. These have slowest photosynthetic rates.

4) Biochemical reactions :

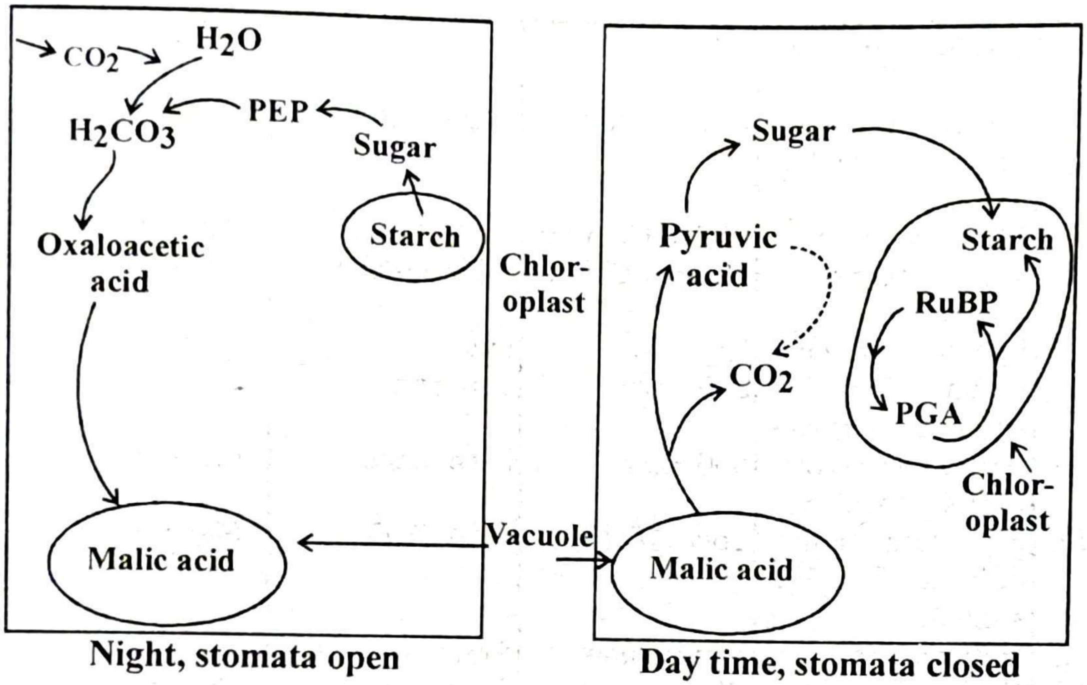


Fig. : CAM Cycle

In xerophytic plants, stomata open during the night & close during the day.When stomata are open, CO_2 is fixed by enzyme PEP-carboxylase to oxaloacetic acid and are stored as malic acid in the vacuole which breaks down in day time to release CO_2 for photosynthesis.

Difference between C_3, C_4 & CAM cycle/plant

	Particulars	C_3-plant (cycle)	C_4-plant (cycle)	CAM plant (cycle)
1)	Site of the cycle i.e. leaf structure (Morphology)	Mesophyll	Mesophyll + bundle sheath i.e. Kranz anatomy	Mesophyll + vacuole
2)	1st stable comp-ound	PGA 3-carbon compound	Oxaloacetic acid (or malic acid) C_4-compound	C_3 & C_4-com-pound in day C_4 in night
3)	CO_2 -fixing enzyme	RuBP carbo-xylase	PEP carboxyl-ase and RuBP-Co (i.e. RuBP Carboxylase)	RuBPCo and PEPCo
4)	CO_2-acceptor	RuBP	PEP	PEP
5)	Dark reaction through	Calvin cycle	a) Hatch & Slack cycle b) Calvin cycle	–

6)	Chlorophylla : ch b ratio	3:1	4:1	≥ 3:1
7)	Isotopic discrimination 13C (1.1% in atm.)	–20 to –40%	–10 to– 20%	–11%
8)	CO_2-concentration (compensation point)	30-70μl/lit.air to 50 ppm CO_2	<10μl/lit.air to 1-5 ppm CO_2	0.2μl/lit. air to <5μl/lit. air
9)	Internal concentration of CO_2 in illuminated leaves.	High 200 ppm	low 100 ppm	medium
10)	Saturation point for CO_2 fixation	500 ppm	lower conc.	medium
11)	Light saturation point as % of full sunlight	Low (10-15)	High (100)	Medium
12)	Habitat	Mesophytes	Arid	Xeric
13)	Example	Wheat	Sugarcane	Cactus
14)	Photosynthetic rate (Under optimal conditions ($mgCO_2/dm^2/hour$)	Medium (15-35)	High (40-80)	Variable and slow (0.5-0.7)
15)	Biomass production	Medium	High	Low
16)	Pigment system (PS) present in chloroplast	Both PSI & PSII are present in all chloroplast	In chloroplast of B.S. cells PSII is absent and hence dependent on mesophyll chloroplast for the supply of $NADPH_2$	–
17)	Presence of calvin cycle enzymes	Mesophyll's chloroplast	Absent in meso phyll's chloroplast	–
18)	Presence of Photorespiration	High	Low	Low
19)	Sensitivity to oxygen	High	Low or negligible	Yes
20)	Water use Efficiency (No. of g. of H_2O to produce 1 g. plant matter)	Low (380-900)	High (250-350)	Very High

21) Optimum temperature	10-25^{0}C	30-45^{0}C	Approx. 35°C
22) Response to CO_2 enrichment	High	Negligible	–
23) Net rate of CO_2 fixation	15-35 mg. of CO_2 per dm^2 of leaf area per hour	40-80mg of CO_2 per dm^2 of leaf area per hour	–

Photorespiration/Glycolate metabolism/C_2-cycle

1) The term 'photorespiration' was firstly used by Decker and reported in tobacco plant.

2) RuBP-carboxylase normally fix CO_2 and forms 2 molecules of PGA (Phosphoglyceric acid). But under High concentration of O_2 (i.e. high O_2/CO_2 ratio) induced by high light checks the production of two molecules of PGA and forms Glycolate (or phosphoglycolic acid) instead of one molecule of PGA. Phosphoglycolic acid or Glycolate is 2-carbon-compound which is the first stable compound hence the name Glycolate metabolism or C_2 cycle. In this process H_2O_2 (Hydrogen Peroxide) is formed which may be dissociated by the enzymes present in peroxisomes.

RuBP (5C) $\xrightarrow{\text{High } O_2/CO_2 \text{ conc.}}$ **Phosphoglycolic acid (2C) + Phophoglyceric acid (3C)**

High O_2:CO_2 Conc. / **High Light**] $\rightarrow$ **glycolate (2-C-compound) 1st stable product** $\rightarrow$ **glyoxylate** $\rightarrow$ **glycine** $\rightarrow$ **Serine** + **CO_2**

3) Photorespiration is stimulated by 4-factors :
   a) High light level : It is a cause for increased photolysis of water (H_2O) which liberates O_2.
   b) High O_2 level.
   c) Low CO_2 level.
   d) High Temperature.

4) Otto warburg in 1920 found that photosynthesis in algae was inhibited by O_2. This occurs in all C_3-plants. This effect

is known as **Warburg Effect**.

5) Site of reactions in Respiration : Cytosol & Mitochondria but site in photorespiration are three. Here three organelles are involved viz. a) Chloroplast. b) Peroxisome and c) Mitochondria.

6) Phosphoglycolic acid is dephosphorylated into glycolate which forms the substrate for photorespiration. Photorespiration of glycolate results in uptake of O_2 and release of CO_2.

7) Photorespiration is light dependent because :

   a) RuBP formation occurs much faster in light than in darkness because operation of calvin cycle needs to form RuBP, requires ATP and $NADPH_2$ (both light dependent products).

   b) Chloroplastic O_2 is more abundant in light due to photolysis of H_2O.

8) Photorespiration is essentially absent in C_4-plants because-

   a) Rubisco (RuBP carboxylase) and other calvin cycle enzymes are present only in bundle sheath cells.

   b) CO_2 concentration of Bundle sheath cells is maintained too high for O_2 to compete with CO_2 due to rapid decarboxylation of malate and aspartate transferred to Bundle sheath from mesophyll cells.

9) Amino acids viz. serine and glycine produced in the glycolate pathway are useful for protein synthesis.

10) Reactions :

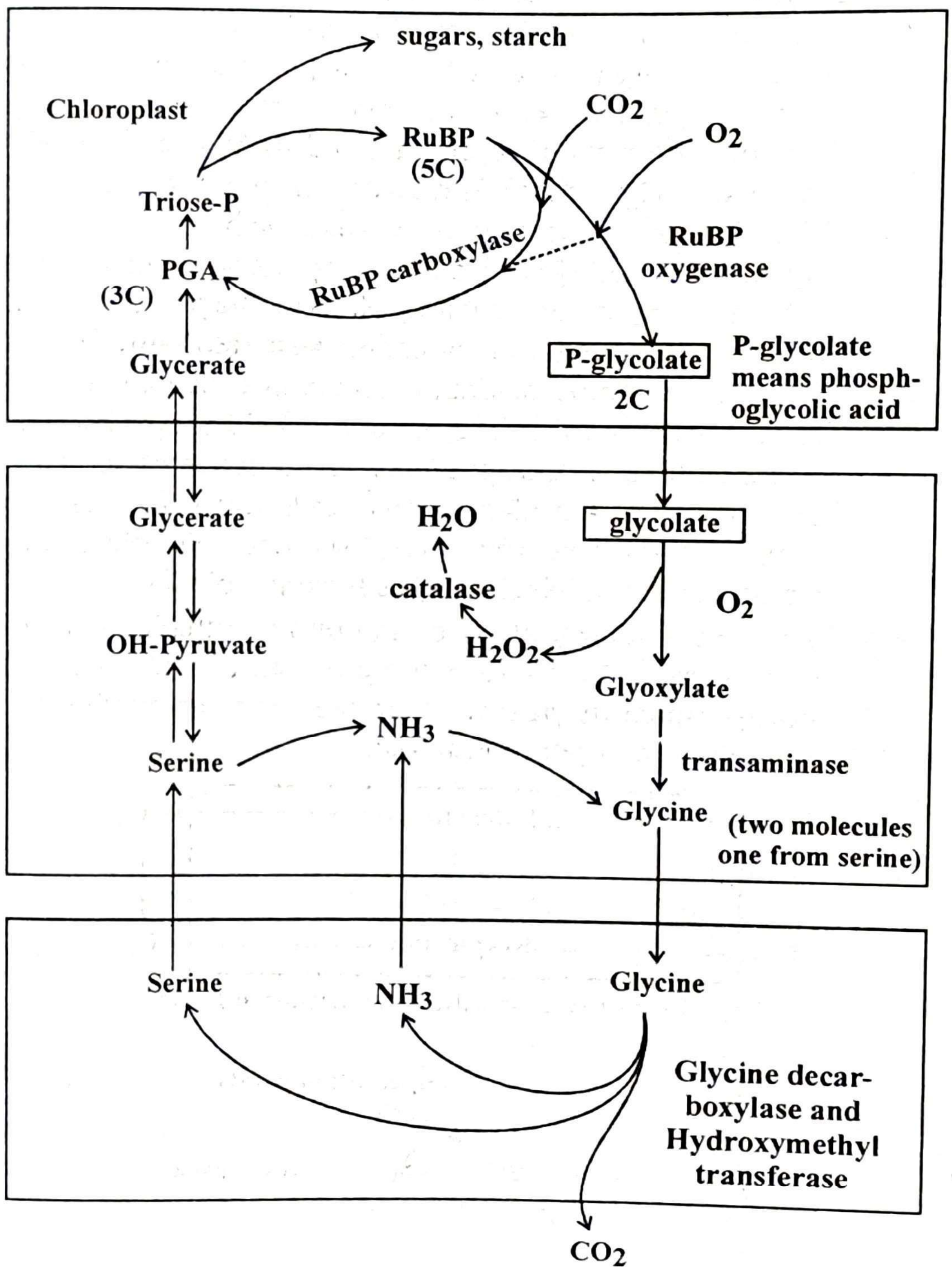


Fig. Glycolate Pathway

Factors Affecting Photosynthesis:

1) **Light** : It is the most important factor of photosynthesis. Light affects through its intensity, quality and duration.The amount of light received by the plant depends on its morphology. The actual requirement of the light intensity depends upon the type of plant and its habitat. Generally average sunlight is sufficient except on rainy or cloudy days. The rate of photosynthesis increases with the increase in light intensity until law of minimum operates. Extremely high light intensity has an inhibitory effect on the photosynthesis and this phenomenon is called **solarization**. During solarization, photo-oxidation occurs in which certain cell constituents are oxidized by O_2 into CO_2. High light intensity also increases the transpiration rate, consequently reducing the water content of mesophyll cells which has also an inhibitory effect on photosynthesis. Low intensity causes stomatal closure which restricts the entry of CO_2.

   The light intensity at which the photosynthetic intake of CO_2 is equal to the respiratory output of CO_2, is called **compensation point**. Therefore net photosynthesis is zero at the compensation point.

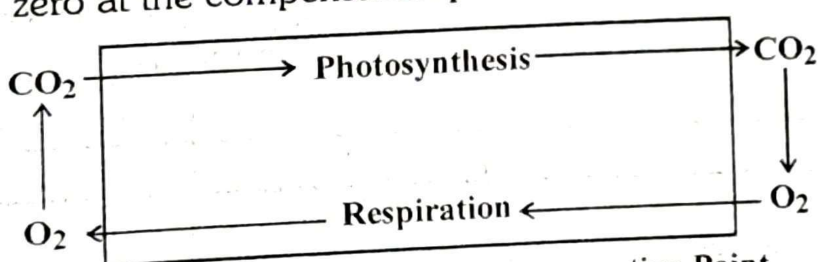


Fig. : Equilibrium is called compensation Point

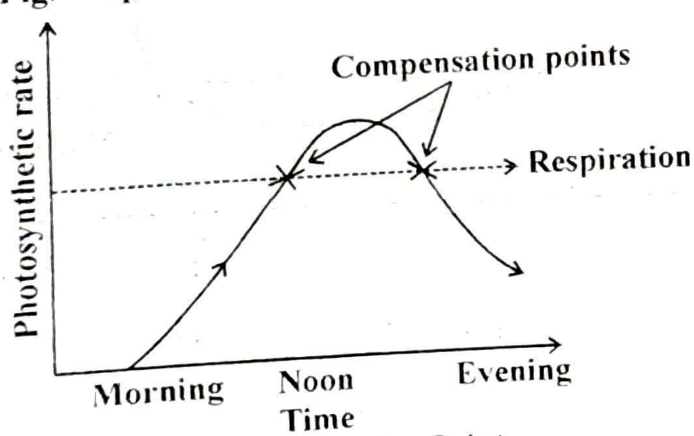


Fig. : Compensation Point

Visible part of the light spectrum i.e. wavelength between 400 nm to 750 nm is the only need for photosynthesis. Heavy absorption of light takes place in the red and next in the blue & violet. Continuous illumination of light also affects the photosynthesis.

2) **CO_2 :** The percentage of CO_2 in the air is 0.03% by volume. At optimum temperature and light intensity, photosynthesis is markedly increased with the increase in CO_2 concentration. But relatively high conc. of CO_2 reduces the photosynthetic rate.

3) **Temperature :** There is a rapid increase in photosynthesis if temp. increases from $10^{0}C$-$35^{0}C$, provided other factors are not limiting. Photosynthetic rate declines with the higher temp. beyond the maximum limit.

4) **Water :** It has no direct effect. The decrease in water content of leaves may cause partial or complete closure of stomatal openings which reduces the diffusion of CO_2.

5) **O_2 :** Oxygen accumulation may retard the photosynthesis. It is a competitive inhibitor of carboxylase thus inhibits photosynthesis in C_3-plants.

6) **Mineral Nutrients :** Magnesium is a part of chlorophyll molecule and other nutrients are necessary for enzymic action and plant metabolism.

All the above factors are external but some internal factors like chlorophyll content; protoplasmic factors & hydration, end product of photosynthesis may also affect the photosynthesis.

*

7 Respiration

Introduction:

Respiration is the breaking down of organic substances viz. carbohydrates, fats and proteins into carbon dioxide, water & energy.

Energy output is the chief product of respiration.

Energy output- through-

a) Slow oxidation of organic food.

b) Exothermic

c) Release of energy = conserved in chemical energy.

Thus,

Respiration = oxidation of foods in living cells.

Nature of respiration : Amphibolic means both catabolic and anabolic.

$$C_6H_{12}O_6 \xrightarrow{\text{oxidation}} CO_2 + H_2O \text{ catabolism}$$

$$ADP \xrightarrow{\text{phosphorylation}} ATP \text{ (Anabolisim)}$$

Fast Oxidation	Slow Oxidation
1) $C_6H_{12}O_6$ $\xrightarrow{\text{Fast release of energy}}$ 673 K.cal. lost as heat or/and light ↓ release of hydrogen at a time 12 H	1) $C_6H_{12}O_6$ $\xrightarrow{\text{Slow release of energy}}$ 673 K.cal. ↓ release of hydrogen in a phase i.e. 6 oxidation steps = 2 H in each step
2) At high temp.	2) At low temp.

3) Non-catalytic	3) Catalytic (enzyme)
4) Example : Burning	4) Example : Respiration

Conclusion : Respiration is a special type of combustion.

Respiration Means-

1) Oxidation of food
2) Complex compound to simple compound
3) Exothermic (Release of heat)
4) Release of Hydrogen
5) Output of H in phases
6) Energy conserved
7) Enzymatically controlled
8) At low temp
9) In living cells.

Respiratory substrate may be carbohydrates, fats and in certain condition protiens.

$$\text{Complex carbohydrate} \xrightarrow[\text{enzyme systems}]{\text{hydrolysis by}} \text{Hexose sugar}$$

$$\text{Fats} \xrightarrow[\text{lipase}]{\text{hydrolysis by}} \text{fatty acids}$$

★ Proteins are utilised only when carbohydrates or fats are not available

★ The first phase of respiration during which carbohydrates were used up had been termed by **Blackman** as the **Floating respiration**.

★ The second phase of respiration in which protoplasmic proteins were used up had been termed by Blackman as the **Protoplasmic respiration**.

★ Most common respiratory substrate is glucose $C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O + \text{energy}$.

Types of Respiration :

- Aerobic
- Anaerobic ≡ Fermentation

(Animal respiration is **essentially aerobic process** and ceases altogether if oxygen is absent).

★ Fermentation is the form of anaerobic respiration carried on by some fungi and bacteria. Substrate of fermentation is present outside the cell and is in the liquid medium.

According to pfeffer, ordinary aerobic respiration occurs in two stages-

a) Splitting of sugar by a no. of steps into alcohol and CO_2.

Sugar →→→→ Alcohol + CO_2

b) Oxidation of alcohol or some intermediate product by atmospheric oxygen into CO_2 and H_2O.

$$\text{Alcohol/other} \xrightarrow[O_2]{\text{oxidation}} CO_2 + H_2O$$

Here, first stage is independent of O_2 and in fact it is Anaerobic respiration. It means Anaerobic respiration is the first part of aerobic respiration.

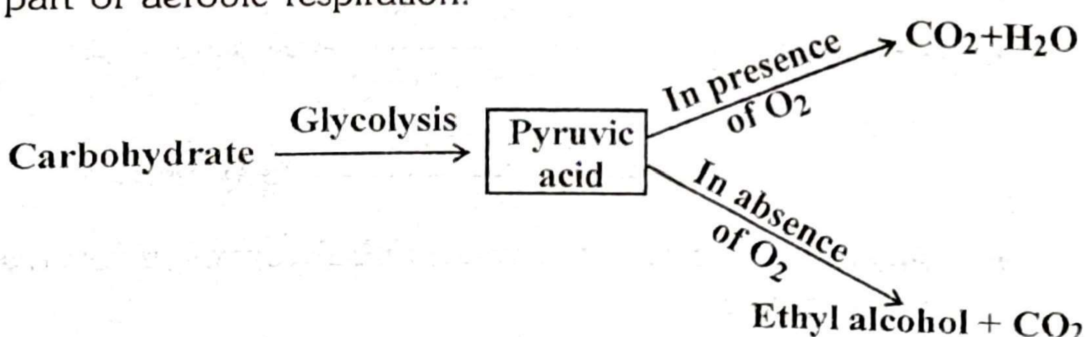


Fig. : Pfeffer - Kostychev Scheme

Mechanism of Respiration :

1) 1st and common stage in respiration in called Glycolysis or EMP Pathway (Embden–Meyerhoff-Parnass) after the name of German scientists who traced the reaction steps.
2) EMP pathway results in two molecules of Pyruvic acid.
3) Second stage is different in the two types of respiration.

I Glycolysis : or EMP Pathway:

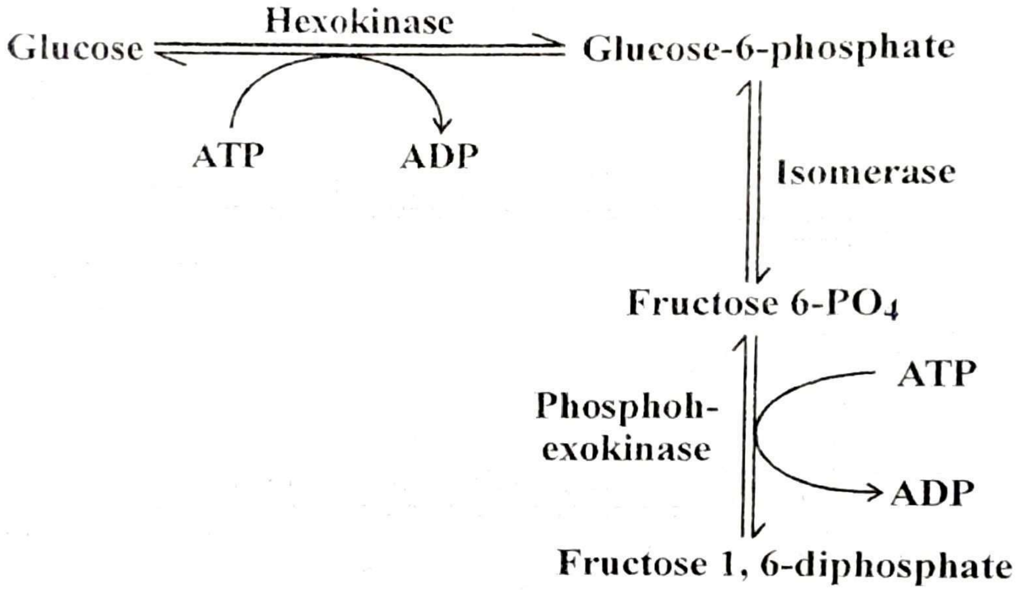
Glycolysis has two phases :

1st Phase : Consumption of ATP (2) i.e. Endothermic

2nd Phase : Production of ATP (4) i.e. Exothermic.

1st Phase of Glycolysis

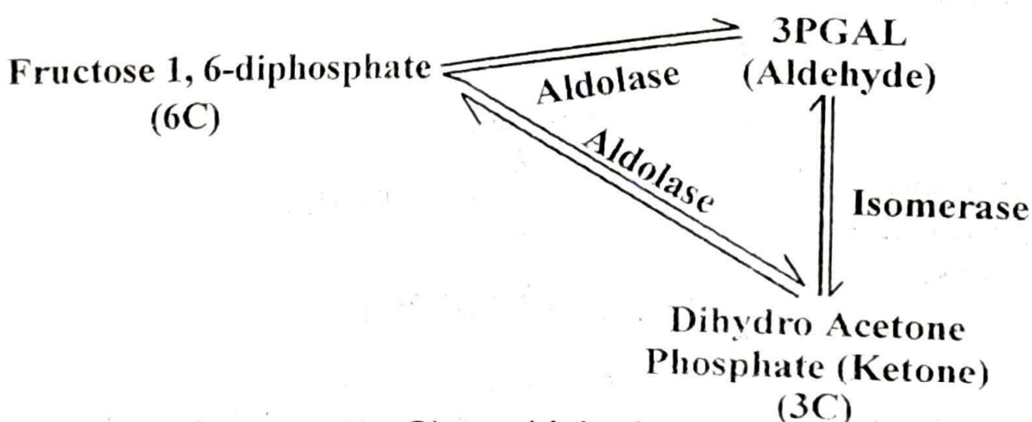
1) Purpose : Phosphorylation of Glucose (i.e. addition of Phosphate PO_4)
2) Requirements : Enzyme (3) + ATP (2)
3) Reactions.



In the first phase, there is loss of two ATP (2ATP).

2nd Phase of Glycolysis :

Here hexose is broken down and reaction are the opposite of calvin cycle.

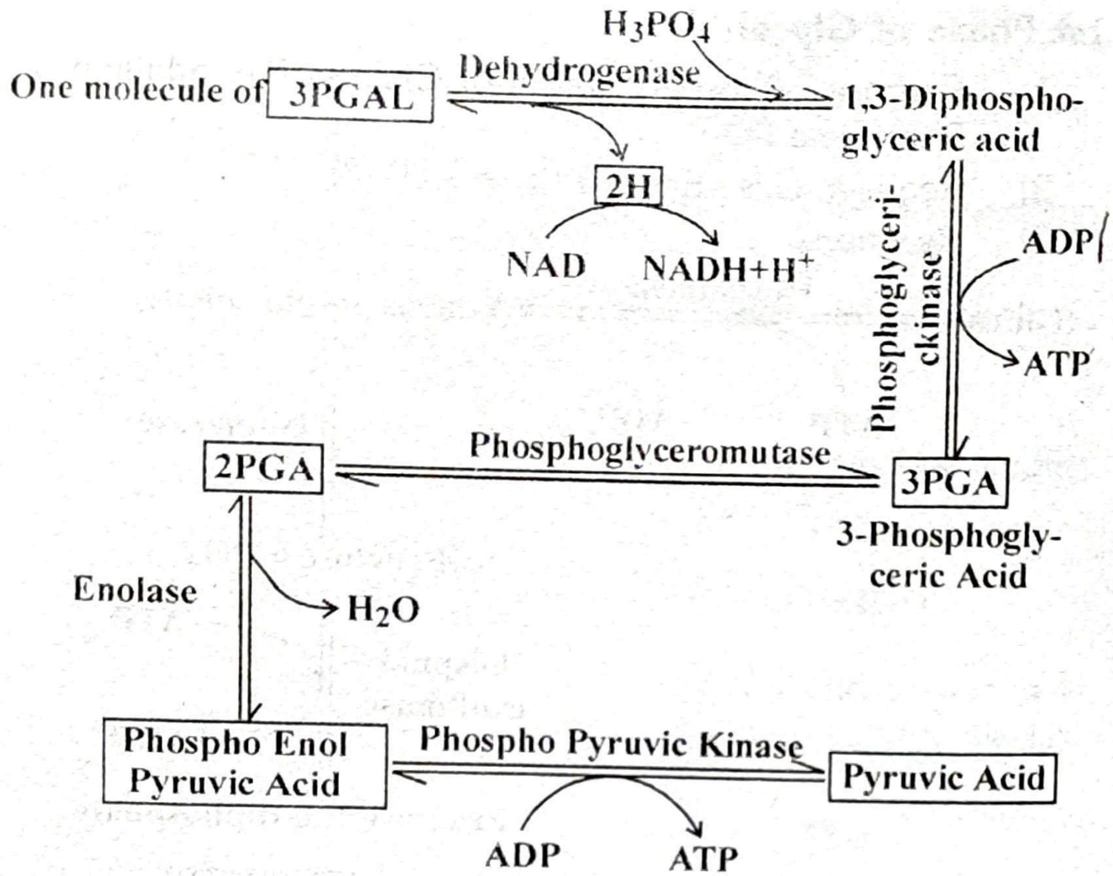


3PGAL : 3-phospho Glyceraldehyde

Products : 3PGAL : One molecule

Ketone : One molecule

But due to isomerase, ketone is converted to aldehyde i.e. 3PGAL, therefore **two** molecule of 3PGAL are obtained.

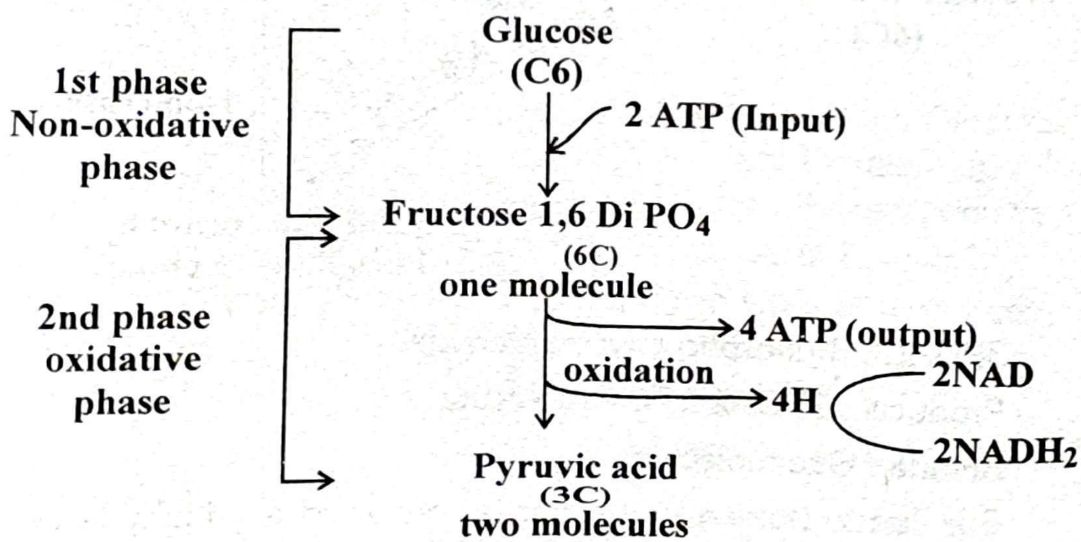


From 1 molecule of PGAL = 2ATP and 1 $NADH_2$ products

From 2 molecule of PGAL = 4ATP and 2 $NADH_2$ products

Note : All reactions of glycolytic pathway are reversible.

Summary of Glycolysis :



Products of Glycolysis :

1) 2 molecules of pyruvic acid (partially oxidised) and further will be oxidised through Link and Krebs cycle.
2) 2 molecules of $NADH_2$: Further will be used for electron transport system to release H_2O.
3) ATP : Energy for any cell work.

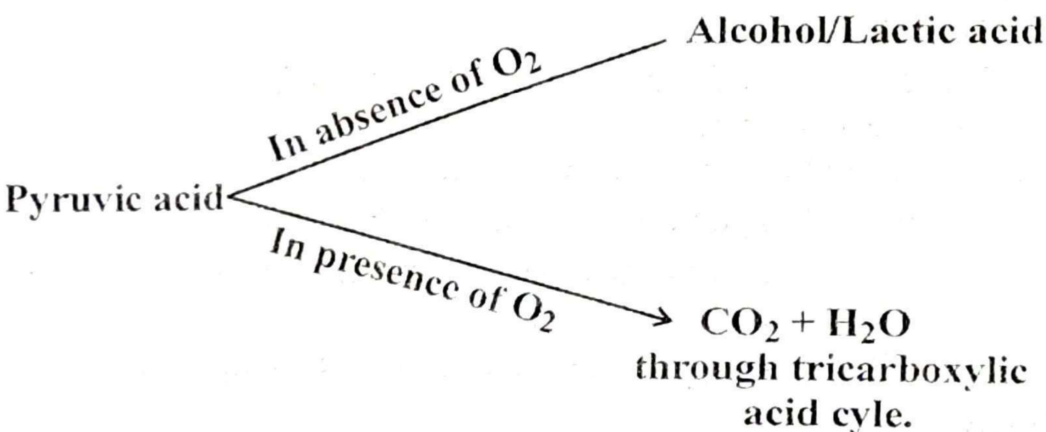
Production = 4ATP

Consumption = 2ATP

Net Production : **2 ATP in glycolysis.**

But 2 molecules of $NADH_2$ will be oxidised aerobically to yield 6 molecules of ATP. Thus total molecules of ATP through glycolysis in presence of O_2 will be 8 instead of 2.

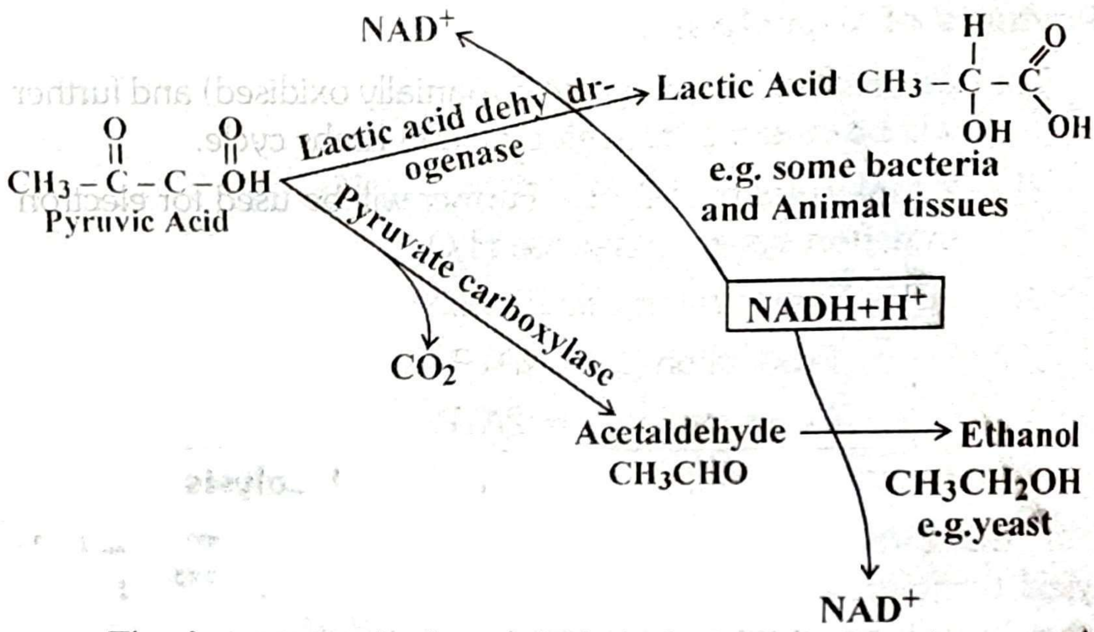
Pyruvic acids obtained through partial oxidation of glycolytic pathway have two fates:



The first fate, which occurs in the absence of oxygen is called Anaerobic respiration (Fermentation) and the 2nd fate which occurs in the presence of oxygen is called aerobic respiration or simply respiration.

Anaerobic respiration ≡ Fermentation:

In the absence of O_2, $NADH_2$ formed during glycolysis can't be reoxidised by O_2, hence for continuous supply of NAD is required for operation of glycolysis. There are two important ways:



The formation of ethanol (Ethyl alcohol) in the absence of O_2 is called Fermentation. The example is yeast. But in muscle tissue of animal (man) and in some bacteria, lactic acid is formed. After excessive work, man is tired only due to the formation of lactic acid in the muscles.

Aerobic Respiration :

It is a slow oxidation and involves 6 oxidation steps.

How Respiration?

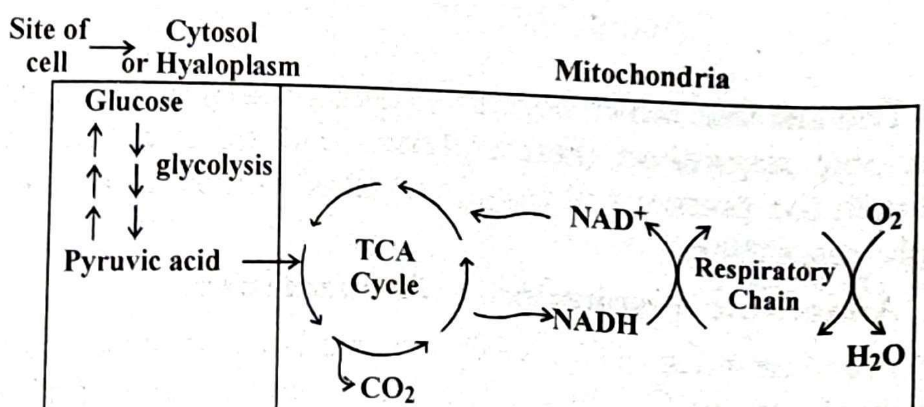
a) Breakdown of glucose (i.e. release of H) through glycolysis + Link + Krebs cycle

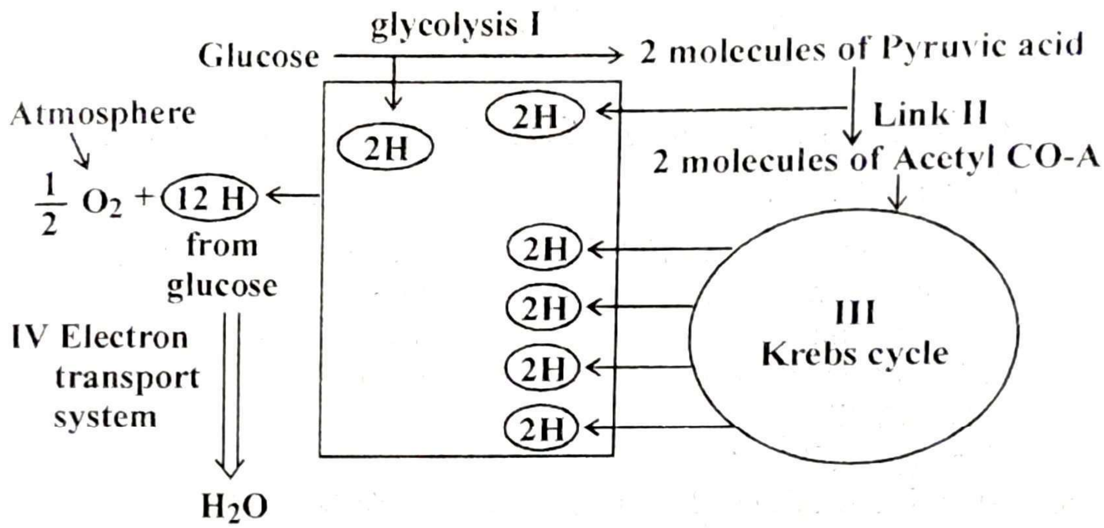
b) Union of all Hydrogen (from glucose) with atmospheric oxygen.

↓

Through Electron Transport System (ETS)

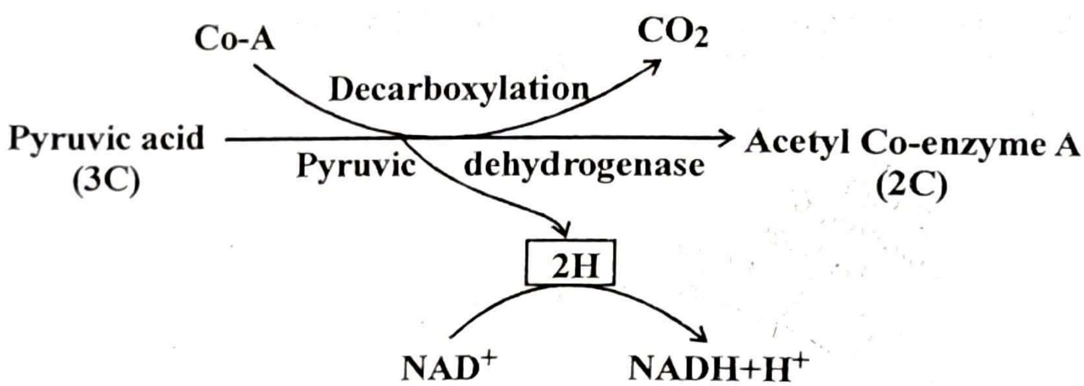
Outline :





II- Link :

Here Acetyle co-enzyme A is formed which is the connecting link between glycolysis and krebs cycle. Hence this stage is called link. There are three changes in the link-



(not NADP because it is in Photosynthesis)

Net result of the reaction :

[Pyruvate+Co–A+NAD^+ → Acetyl Co–A + $NADH_2$ + CO_2]×2 molecules

Release : $2CO_2$ (two molecule of CO_2) + 4H

III. Krebs cycle/citric acid cycle/Tricarboxylic acid cycle

↑ Name of scientists — ↑ First product of reaction — ↑ Nature of organic acid produced in the reaction.

Under aerobic conditions pyruvic acid is oxidised through a 'Tricarboxylic acid cycle' given by **Wood** et al (1942) and **Krebs** (1943).

Energy is released due to breaking of bond of carbon-carbon into CO_2.

Difference between Calvin and Krebs Cycle

Calvin Cycle	Krebs Cycle
1) Initiator molecule : RuBP (5C) 5-carbon compound	1) Oxaloacetic acid (4C) 4-carbon compound
2) Raw materials : – CO_2 (atmosphere) – H_2 ($NADPH_2$) – Energy (ATP)	2) Acetyl Co-A Source : Oxidation product of glucose.
3) 1st stable product : PGA(3C)	3) Citric Acid (6C)
4) Product – Food (hexose)	4) Products – CO_2 – H_2 – Energy
5) Nature : Endothermic & Reduction	5) Exothermic and oxidation
6) Site : Chloroplast	6) Mitochondria.

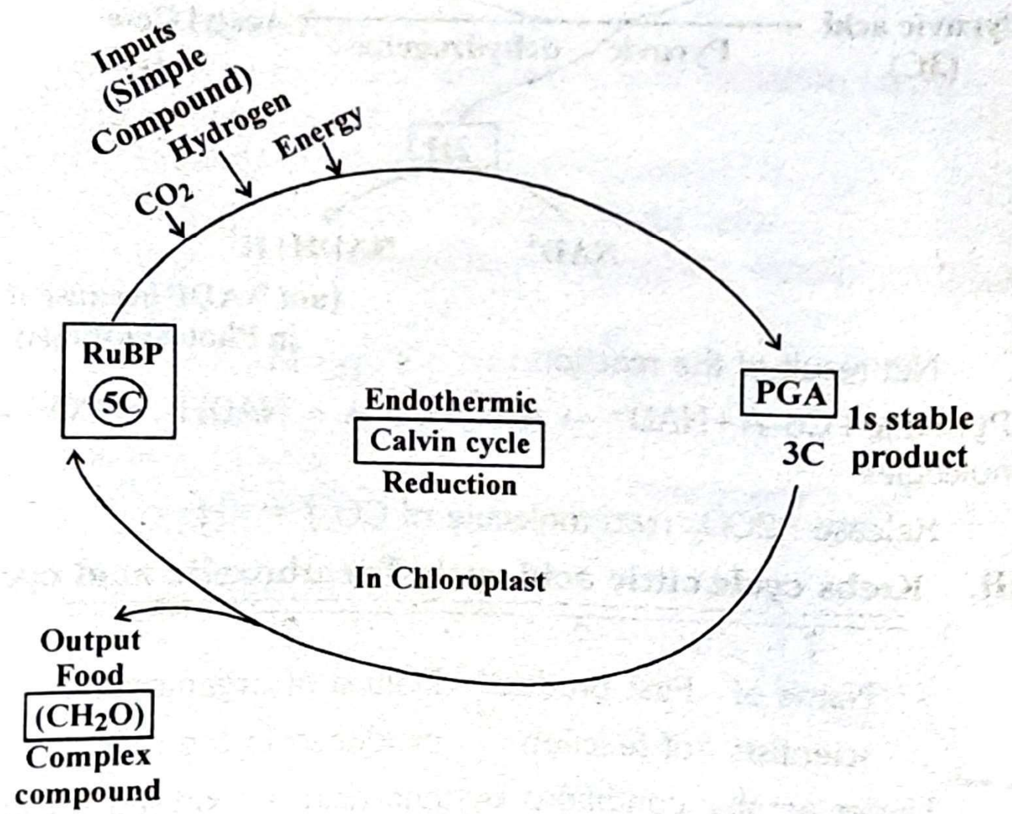


Fig. Calvin Cycle

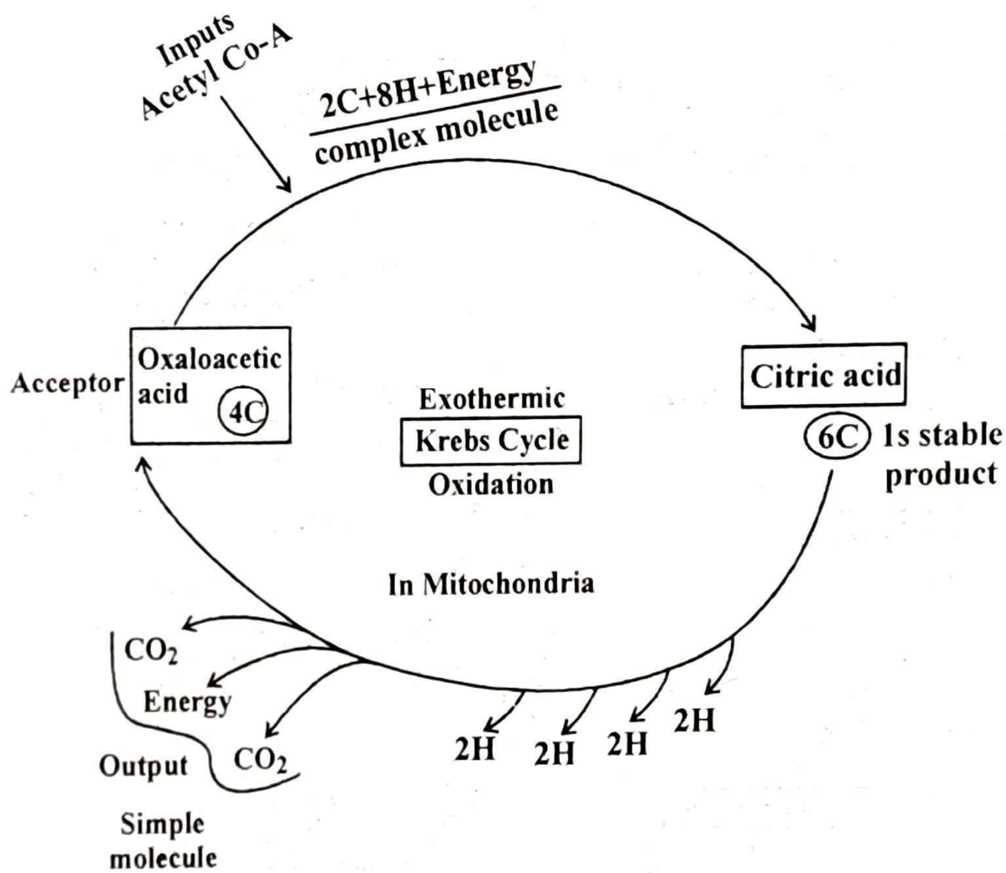


Fig. Krebs Cycle

Conclusion : Both calvin and Krebs Cycles are antiparrallel reactions.

Q. What happens during krebs cycle :

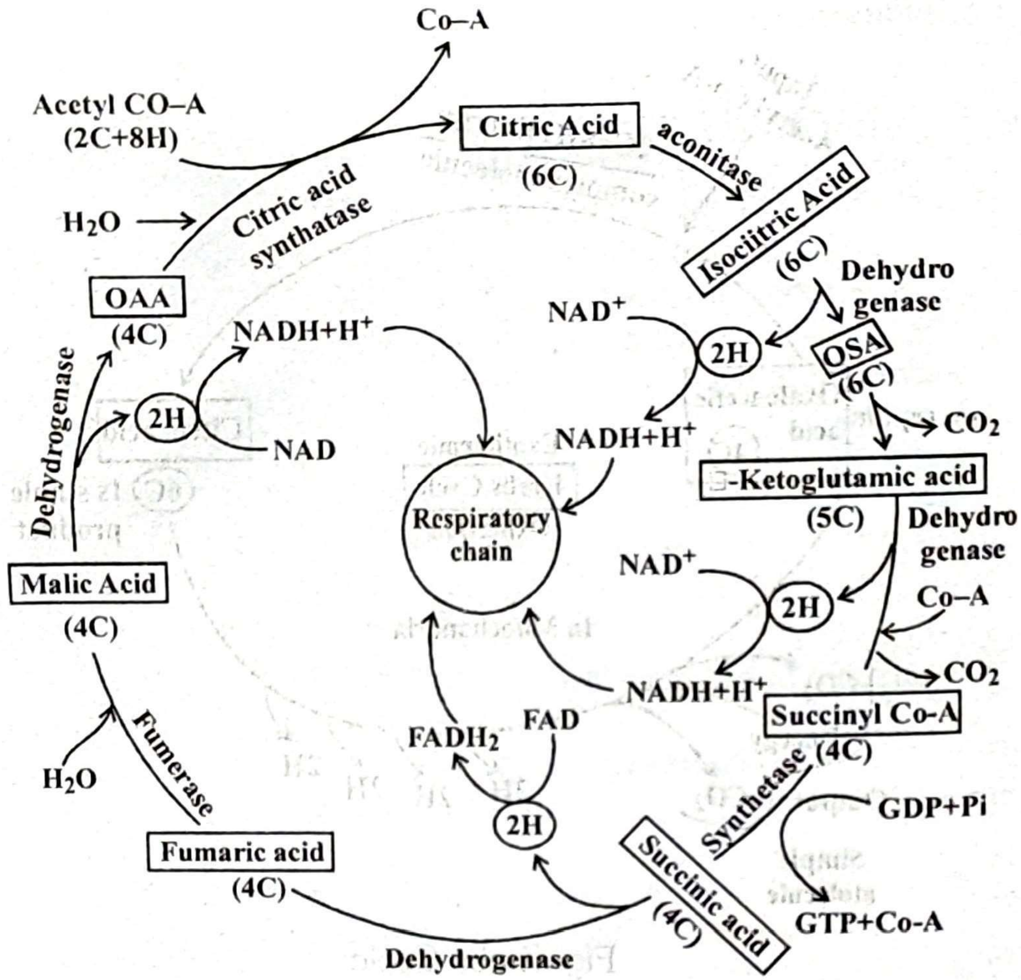
a) Decarboxylation (CO_2-removal)

b) Oxidation (H-removal)

c) Phosphorylation (Energy production)

d) All

Ans. (d)



OAA : Oxaloacetic acid
OSA : Oxalosuccinic acid
GTP : Guanosine Triphosphate
GDP : Guanosine Diphosphate
FAD : Flavin adenine dinucleotide

Fig. Krebs Cycle/TCA cycle

Note : All reactions of krebs cycle are reversible, but the reaction of link are not reversible.

No oxygen is taken up in the TCA cycle itself but is taken up in the respiratory chain.

★ Enzyme : Decarboxylase → For removal of CO_2
acts twice; specific action on
i) Oxalo succinic acid] source of CO_2
ii) α-Ketoglutamic acid] in K.C. (Krebs cycle)

Total no. of CO_2 produced in K.C. from 2 molecule of Acetyl Co–A →**$4CO_2$**

★ Enzyme : Dehydrogenase → For removal of Hydrogen

Dehydrogenase = De + Hydrogenase
↓
means removal

It works 4 times specifically at :

H- donor in K.C.
i) Isocitric acid → 2H → NAD^+
ii) a-Ketoglutamic acid → 2H → NAD^+
iii) Succinic acid → 2H → FAD^+
iv) Malic acid → 2H → NAD^+

H-acceptor in K.C.

Major acceptor of H → NAD
Minor acceptor of H → FAD
Total no. of 2H released in K.C. – $\boxed{2H}$ × 8 = **16H**

★ **ATP production through K.C.**

Breaking down of succinyl Co-A
↓
Releases chemical bond energy.
GDP + Pi → GTP; (Pi means inorganic phosphate)
GTP + ADP → GDP + $\boxed{ATP}$

Since one molecule of ATP is produced from one molecule of Acetyl Co-A
∴ two molecule of Acetyl Co-A → **2ATP**

Phosphorylation :

$$\text{ADP + Pi} \xrightarrow[\text{(7–11 K.cal)}]{\text{Energy}} \text{ATP}$$

if Light energy then called photophosphorylation e.g. photosynthesis here process is transformation of energy	if chemical bond energy then called Trans/substrate phosphorylation e.g. K.C. Process is transfer of energy	if oxidation energy then called oxidative phosphorylation e.g. electron transport system (ETS)

IV. Electron Transport System (ETS)/Respiratory Chain

Here oxidation of NADH+H^+ and FADH+H^+ occurs.

i) Electron donor is Hydrogen
ii) Electron carriers – Cytochrome (in F_1 particle of Mitochondria)

iii) Electron Acceptor – Oxygen (from atmosphere)

iv) Production of H_2O and ATP

$NADH_2$ & $FADH_2$ are the only temporary storage place for electrons.

Respiratory chain is the system of mitochondrial enzymes and electron carriers through which the re-oxidation of NADH to NAD^+ under aerobic conditions by transfer of electrons from NADH to O_2. Respiratory chain also transfer the electrons from succinic acid to O_2.

$$NADH + \frac{1}{2} O_2 + H^+ \longrightarrow H_2O + NAD^+$$

$$\underset{\text{succinic acid}}{COOHCH_2\ CH_2COOH} + \frac{1}{2} O_2 \longrightarrow H_2O + \underset{\text{Fumaric acid}}{\begin{matrix} CHCOOH \\ \| \\ CHCOOH \end{matrix}}$$

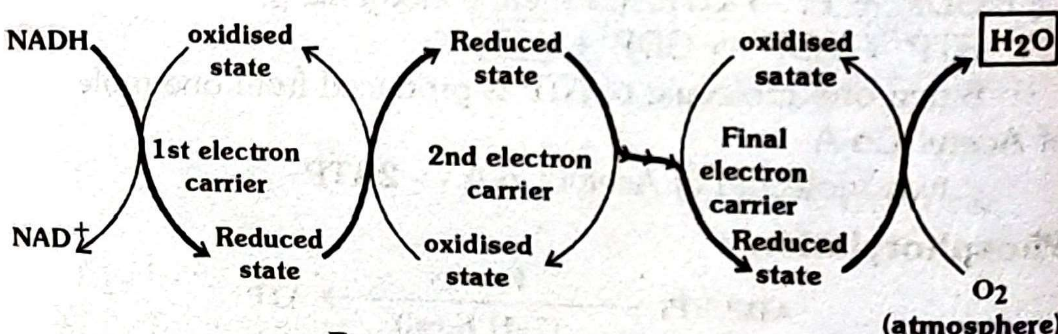


Fig. : Respiratory Chain

O_2 is the final electron acceptor

No. of released $NADH_2$ /$FADH_2$:

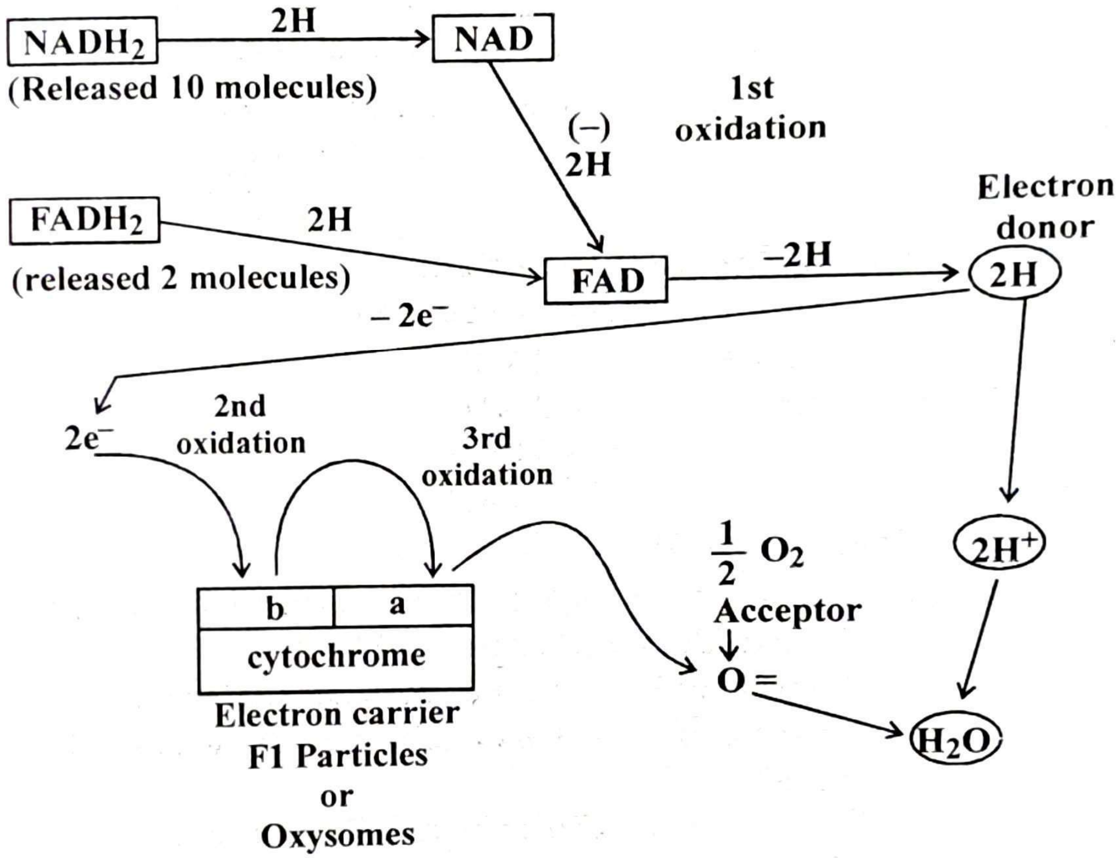
Released $NADH_2$ molecule :

Through Glycolysis	$= 1\times2 = 2$ $NADH_2$
Link	$= 1\times2 = 2$ $NADH_2$
K.C.	$= 3\times2 = 6$ $NADH_2$
Total $NADH_2$	$= 5\times2 = 10$ molecule

Released $FADH_2$ molecule :

only through K.C. $= 1\times2 = 2$ $FADH_2$

Oxidation Steps of $NADH_2/FADH_2$ in ETS



In the oxidation of one molecule of reduced NAD (i.e. $NADH_2$) to NAD^+, 3 molecules of ATP are released, one in the 1st oxidation step of $NADH_2$; one in the 2nd oxidn. step of reduced cytochrome b; and one in the 3rd oxidation step of reduced cytochrome a.

i.e. $NADH_2 \rightarrow NAD^+ + 2H + 1ATP$

$$2H \rightarrow 2H^+ + 2e^- + 2ATP$$

$$\overline{NADH_2 \rightarrow NAD^+ + 2H^+ + 2e^- + 3ATP}$$

$\therefore$ 10 Molecules of $NADH_2$ released $3 \times 10 = 30$ ATP

In the case of succinic acid oxidation, NAD step (i.e. 1st oxidation step) is bypassed and therefore only 2 molecules of ATP are generated; one in the oxidation of reduced cytochrome b; and one in the oxidation of reduced cytochrome a. According to Bidwell (1979) NAD^+ transfers 2H to FAD.It constitutes 1st oxidation step.

$$FADH_2 \rightarrow FAD^+ + 2H^+ + 2e^- + 2ATP$$

$\therefore$ 2 molecules of $FADH^2$ release $2 \times 2 = 4ATP$

$\therefore$ Total No. of ATP produced in ETS = 30ATP
+ 4ATP
34ATP

Energy released during respiration:

1) On the basis of stages of respiration:
   a) glycolysis = 2ATP
   b) Krebs cycle = 2 ATP
   c) ETS = 34ATP
   38 ATP

2) On the basis of site:
   a) Enzyme of glycolysis : On cytosol (cytoplasmic soln.) i.e. outside Mitochondria : = **2ATP**
   b) Enzyme of K.C. : On Perimitochondrial space
   Enzyme of ETS : On cytochromes (oxysomes/F_1 Particles)
   i.e. Inner membrane of Mitochondria
   thus within Mitochondria = 2ATP of K.C.
   34 ATP of ETS
   36 ATP

3) On the basis of phosphorylation :
   a) Oxidative phosphorylation = 34 ATP
   b) Substrate/Trans phosphorylation = 4ATP
   (i.e. direct oxidation of substrate) = 38ATP
   2 ATP in glycolysis + 2ATP in K.C.

4) On the basis of 3 stages excluding ETS :
   a) Glycolysis = 8 ATP
   b) Link = 6 ATP
   c) K.C. = 24 ATP
   38 ATP
   (through respiratory chain) **in presence of O_2**

5) On the basis of two stages excluding link and ETS:
   a) Glycolysis = 8 ATP
   b) Krebs cycle = 30 ATP
   38 ATP
   (in presence of O_2 through ETS)

6) On the basis of reactions:

S.No.	Compound to be oxidised	Compound formed after oxidation	H-acceptor	No. of ATP
1.	3-Phosphoglyceraldehyde	1,3-diphosphoglyceric acid	NAD^+	$2\times3 = 6$ (2 means 2 molecules of NAD^+)
2.	1,3-diPGA	3-PGA	--	$2\times1 = 2$
3.	Phospho enol Pyruvic acid	Pyruvic acid		$2\times1 = 2$
4.	Pyruvic acid	Acetyl Co-A	NAD^+	$2\times3 = 6$
5.	Isocitric acid	Oxalosuccinic acid	NAD^+	$2\times3 = 6$
6-	α-Ketoglutaric acid	Succinic acid	NAD^+ (+ATP)	$\left.\begin{matrix}2\times3 = 6\\2\times1 = 2\end{matrix}\right\}=8$
7.	Succinic acid	Fumaric acid	FAD^+	$2\times2 =4$
8.	Malic acid	Oxaloacetic acid	NAD^+	$2\times3 = 6$
Total no. of produced ATP			= 40 ATP	
Total no. of Consumed ATP			= 2 ATP	
Net gain of ATP			= 38 ATP	

Reaction Formula of Respiration :

Outputs :

a) No. of CO_2 molecule through Link = 2
KC = 4

Total molecules released during respiration = $\mathbf{6CO_2}$

b) No. of H_2O molecule through ETS = $(1\times10)+(1\times2)$ = $\mathbf{12H_2O}$

10 means 10 molecules of $NADH_2$

2 means 2 molecules of $FADH_2$

c) No. of net ATP produced = 38ATP

Inputs :

a) Glucose : $C_6H_{12}O_6$

b) Oxygen : $\frac{1}{2}O_2$

∴ Formula : After balancing the above inputs & outputs :

$$C_6H_{12}O_6 + 6O_2 + 6H_2O = 6CO_2 + 12H_2O + 38ATP$$

$$\text{or } C_6H_{12}O_6 + 6O_2 + 6H_2O = 6CO_2 + 12H_2O + 686 \text{ K.cal}$$

Efficiency of respiration:

When glucose is a respiratory substrate, 686 K.cal. is released where some energy is conserved as 38ATP molecules. When one ATP molecule is hydrolysed, the energy released is about 7.6 K.cal per mole of the terminal phosphate group in ATP.

$$\therefore \text{Efficiency} = \frac{38 \times 7.6}{686} = 42\%$$

Thus the efficiency of respiration is 40-50%. It means respiration is partially efficient and rest energy is lost as heat energy. The temp. of the test tube containing germinating seed is increased only due to fast respiration. In the dormant seed, respiration is slow.

Q. During aerobic respiration of glucose, a plant cell released 42 molecules of CO_2. How many ATP will be produced?

Soln: Eqn: $C_6H_{12}O_6 + 6O_2 + 6H_2O \rightarrow 6CO_2 + 12H_2O + 38ATP$

6 molecules of CO_2 produced when 38 ATP are released

∴ 42 molecules of CO_2 produced when are $\frac{38}{6} \times 42 = 266$ ATP.

Respiratory Quotient/Respiratory Ratio:

R.Q. is the ratio of the volume of CO_2 released to the volume of O_2 absorbed in the respiration. It is also called respiratory ratio(RR).

$$R.Q. = \frac{\text{Volume of released } CO_2}{\text{Value of absorbed } O_2}$$

a) R.Q. = 1, when substrate is carbohydrate (hexose)

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 686\text{K.cal}$$

b) R.Q. < 1 i.e. R.Q. is less than unity. when respiratory substrate is highly reduced food.

i) respiration of fats & protein :

$$\underset{\text{(fat)}}{2C_{51}H_{58}O_6} + 145O_2 \rightarrow 102CO_2 + 98H_2O$$

When substrate is **Fat**, R.Q. = **0.7**

when substrate is **Protein**, R.Q. = **0.8 – 0.9**

Respiration of Protein
- with amide formation, RQ = 0.8
- With ammonia formation, RQ = 0.99

ii) Respiration in succulent plants and red leaves (i.e. xerophytes e.g. opuntia)

Here oxidation is incomplete.

$$2C_6H_{12}O_6 + 3O_2 \xrightarrow[\text{Oxidation}]{\text{Partial}} \text{Malic acid} + 3H_2O + 386\text{K.cal}$$

$$R.Q. = \frac{CO_2}{O_2} = \frac{O}{3} = 0$$

c) R.Q. > 1 i.e. R.Q. is more than unity

when respiratory substrate is highly oxidised food.

i) Organic adds :

$$\underset{\text{oxalic acid}}{2(COOH)_2} + O_2 \rightarrow 4CO_2 + 2H_2O + 60.2\text{ K.cal}$$

$$R.Q. = \frac{CO_2}{O_2} = \frac{4}{1} = 4$$

$$\underset{\text{malic acid}}{C_4H_6O_5} + 3O_2 \rightarrow 4CO_2 + 3H_2O$$

$$R.Q. = \frac{CO_2}{O_2} = \frac{4}{3} = 1.3$$

ii) Anaerobic respiration :

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2CO_2 + 21\text{ K.cal}$$

$$R.Q. = \frac{CO_2}{O_2} = \frac{2}{0} = \infty \text{ (infinity)}$$

The R.Q. of a plant material is measured by Ganong's Respirometer.

Difference between-

Aerobic respiration	**Anaerobic respiration**
1) Oxidation of substrate in presence of O_2.	1) Oxidation in absence of O_2
2) Intermolecular respiration $C_6H_{12}O_6 + O_2$	2) Intramolecular respiration
3) Complete oxidation	3) Partial oxidation
4) Energy output → higher glucose → 38ATP	4) Energy output → lower Glucose → 2ATP
5) End product $C_6H_{12}O_6+6O_2=>6CO_2+6H_2O+38ATP$	5) End product $C_6H_{12}O_6=>2CO_2+2C_2H_5OH+2ATP$ or $C_6H_{12}O_6 \rightarrow \underset{\text{lactic acid}}{2C_3H_6O_3}+2ATP$
6) Oxidation steps → 6 (six)	6) Oxidation step → 1 (one)
7) Dependent on mitochondria	7) Independent of mitochondria
8) Hydrogen acceptors → NAD^+ + FAD^+	8) Hydrogen acceptor → NAD^+ only
9) Phosphorylation : a) Oxidative and b) Substrate	9) Phosphorylation → Trans (substrate) only.
10) R.Q. → 1, >1, <1, or 0	10) R.Q. : Infinity (∞)

Difference between Respiration and Photorespiration

Respiration	**Photorespiration**
1) Respiratory substrate : carbohydrate, fat or protein	1) Glycolate
2) Substrate may be recently formed or stored one	2) Substrate is always recently formed
3) Process of respiration occurs in cytoplasm + Mitochondria	3) Process occurs in chloroplast + Peroxisomes + mitochondria
4) Hydrogen peroxide (H_2O_2) is not formed	4) H_2O_2 is certainly formed
5) Several ATPs are produced	5) No ATP
6) It occurs in light and Dark both.	6) Only in light
7) Occurs in all living cells.	7) Only in chlorophyllous cells.
8) Not sensitive to rise in temperature	8) Photorespiration is high at 25°-35°C.
9) No Transamination Occurs	9) Transamination occurs.

Factors affecting respiration (aerobic) :

External Factors :

1) Temperature : The increase in temperature increases the rate of respiration following the vant **Hoff's law**. (vant Hoff's law – the respiration rate increases two or three times for every rise of 10°C i.e. $\mathbf{Q_{10}=2}$ or $\mathbf{Q_{10}=3}$). This marked increase in respiration rate is only in between the range of 0°-45°C. The optimum temp. of respiration is 30°C. At high temperature, there is a decrease in respiration rate and the responsible factor is called Time Factor. At very low temp., the respiration rate is very low i.e. insignificant. Therefore vegetables and fruits are generally stored at very low temperature just to minimise the catabolic effects of respiration.

2) Light : The effect of light is indirect on respiration rate. Light increases the respirable material by increasing photosynthesis. Light also increases the temperature. Light affects the opening and closing of stomata also.

3) Concentration of O_2 in the atmosphere : Oxygen is essential for aerobic respiration but its concentration in the atmosphere is almost constant thereby not affecting the rate.

4) CO_2 concentration : Since its concentration in the atmosphere is also constant, therefore it has no effect on respiration rate. But its concentration is variable in the soil air, therefore its high concentration in the soil air, inhibits all those activities of plant which require energy.

5) Water : The slight change in the water content does not affect the respiration rate. The shortage of water may increase the respiration rate but the very low content of water (e.g. dry seeds and stored tubers) minimises the respiration rate.

6) Injury : The sugar content of the injured or wounded portion of the plant is suddenly increased because the conversion of starch to sugar is increased due to the increase in the rate of respiration.

7) Certain chemical compounds : Certain enzymatic inhibitors like cyanides, azides, carbon monoxide, iodoacetate chloroform, ether etc. reduces the rate of respiration.

8) Mechanical effects: The gentle rubbing or bending of the leaf blade increases the respiration rate but high wind or storm closes the stomata to cut off the O_2 supply.

Internal Factor:

9) Protoplasmic factors : Younger cells which have more of active protoplasm respire more rapidly than older cells. The older cells have less protoplasm due to larger vacuoles. The rate is also affected by the quantities of respiratory enzymes present in the protoplasm. In the old age (i.e. senescence), the respiration rate declines.

10) Concentration of respiratory material : If other factors are not limiting, the respiration rate increases with the increase in the respiratory substrate.

Pasteur Effect :

Generally the increase in respiratory substrate or oxygen, increases the rate of respiration.

But there are many cases where oxygen reduces the rate of sugar breakdown and even conserve it, is called Pasteur Effect.

Climacteric Rise :

The rate of respiration varies with the age of respirable cell. In merismatic cells respiration is high and becomes steady in the growing stages. In the maturing fruit or in the ripening of fruits, there is the production of ethylene which increases the respiration rate. This rise in the rate of respiration is called the climacteric rise.

*

8 Enzymes

Meaning :

Enzyme = En + Zyme = Greek words

means

In ↓ **Living** ↓

The word 'enzyme' was coined by W.kuhne (1878) while working on fermentation. Enzymes may be defined as organic substances capable of catalysing chemical reactions in the living systems. These are the following points necessary for to be the enzyme :-

a) proteinaceous substance

b) Biological and organic catalysts.

c) required in small quantity.

d) Specific in nature.

Thus enzymes alter the rate of reaction without affecting the equilibrium.

Types :

(a) On the basis of structure :

1) Simple protein enzymes : such enzymes are wholly made up of proteins e.g. trypsin, pepsin, amylase, urease etc.

2) Conjugated enzymes : In such enzymes, non-protein parts are also the structural components. The protein part is called **Apoenzyme** and non-protein component is called **cofactor**.

Isoenzymes : Such enzymes are different in moleculer structure but are similar in Function e.g. Lactic acid dehydrogenase (LDH).

Conjugated enzymes = Protein component + Non-protein component

Protein component → Apoenzyme

Non-protein component → Cofactor

(I) Coenzymes organic part and easily separable from apoenzyme e.g. NAD, NADP, Co-A, ATP

(II) Prosthetic group Firmly adhered to the apoenzyme e.g. FAD

(III) Metal activators e.g. Fe^{2+}, Co^{2+}, Mg^{2+}, Zn^{2+}, Fe as in cytochrome

(b) On the basis of presence :

1) Inducible enzyme : Such enzymes do not occur in the absence of substrate e.g. Nitrate Reductase (Nitrate reductase is found in the nodules of leguminous crop.)
2) Non-Inducible enzyme : Such enzymes are present at all the times e.g. mostly enzymes.

Mode of Action :

The action of the enzyme depends upon a combination of the enzyme and the substrate molecules to form an enzyme-substrate complex. The enzyme substrate relationship is often compared to as **'Lock and Key'** theory, proposed by Fischer (1894). Another theory called **Induced-Fit hypothesis** was proposed by **Koshland** (1959). According to the latter theory, the attachment of substrate to the enzyme brings about a three dimensional structural change in the enzyme.

Classification : The enzymes are broadly classified into six groups:

1) Transferases : Such enzymes catalyse the transfer of one carbon group to another molecule e.g. Hexokinases, transaminases etc.
2) Hydrolases : Such enzymes catalyse the hydrolysis of the compound. i.e. the addition of the water molecule e.g.
   $C_6H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$
   Invertase, amylase, esterase, phosphatase, etc.
3) Oxido-reductases :
   3a) Oxidases : Such enzymes catalyse the oxidation with molecular oxygen e.g. cytochrome oxidase, peroxidase.

3b) Dehydrogenase : Catalyse the removal of 'H' through oxidation concerned with oxidative phosphorylation e.g. Alcohol dehydrogenase (i.e. for hydrogen transfer)

3c) Reductases : These enzymes cause addition of 'H' or electron (e^-) and the removal of O_2 e.g. Nitrate reductase.

4) Lyases : These enzymes cause the removal of a group of atoms from the substrate and cause addition of 2nd group at this (double) bond without affecting hydrolysis, oxidation and reduction. e.g. carboxylase, Fumerase, adolase.

5) Isomerases : These enzymes are the responsible for the isomeric changes through rearrangement.

6) Ligases or Synthatases : These catalyze the synthesis of different types of bonds e.g. polymerase, RNA synthatase.

Nature and Properties of Enzymes

1) Enzymes **are specific** in nature means specific in reaction with substrate.
2) Enzymes are **colloidal** in nature and thus provide large surface area for reaction.

3) Enzymes are made up of either only Apoenzyme or Apoenzyme + Co-Factor.
4) are required in extremely small amounts.
5) remain unaffected in the reaction.
6) Organic catalyst.
7) are pH regulated.
8) Enzymes are amphoteric protein (means react with acidic and alkaline both substances)
9) Thermolabile (means heat sensitive)
10) Enzymic activity can be inhibited.
11) Enzymic reactions are reversible but forward reaction is more.

Factors affecting Enzymic reactions :

1) Substrate Concentration : An increase in the concentration of the substrate firstly increases the rate of the reaction but when all the active sites of the enzyme surface are occupied by the substrate moleucle, the increase is stopped. And

there is no effect of the further increase in substrate conc. on the rate of reaction. This is because of the limiting effects of the enzyme concentration.

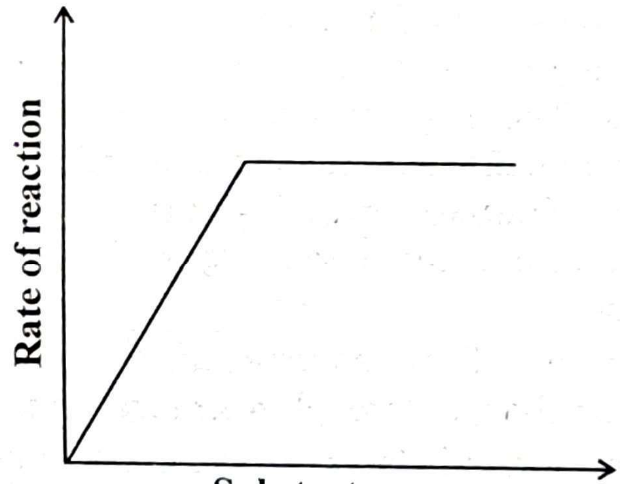


Fig. : Relationship between the substrate conc. and the rate of reaction.

2) Enzyme concentration : Firstly there is an increase in the rate of reaction with the increase in enzyme concentration but the rate of reaction stops at a point and becomes constant when substrate conc. becomes the limiting factor.

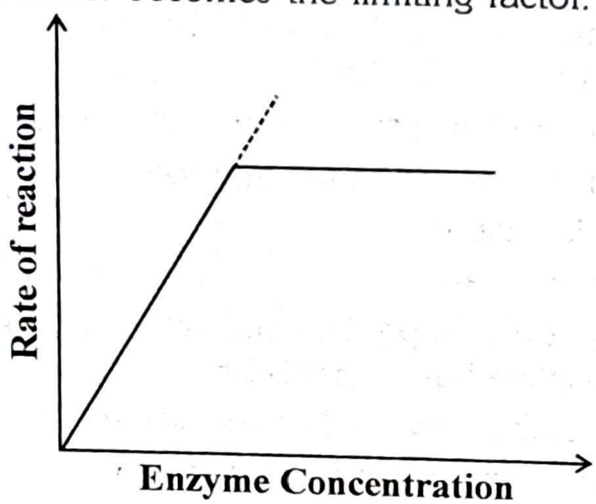


fig. Effect of enzyme conc. on the rate of reaction.

3) Temperature : The enzymic reaction rate increases twice (i.e. doubles) for every rise of 10°C within the certain limit. i.e. $Q_{10} = 2$. At 0°C enzymatically active reaction rate becomes zero and at higher temperature i.e. 55°–60°C, the Denaturation of enzyme takes place (i.e. the loss of natural properties). However, the optimum temp is 30°C.

4) Hydrogen ion concentration (pH) : The pH between 7–7.5 is ideal for the normal enzymic activity but there are certain enzymes like pepsin requires very low pH i.e. 1.5–3.0 whereas enzymes like Trypsin are active even at high pH.

5) Hydration : In the seeds, the amount of water is too less so no enzymic activity is observed. With the increase in the amount of water, enzymes become active and seed starts to germinate.

6) Concentration of the End product : Enzymic reactions are reversible in nature and acts on the 'Mass action' principle. Therefore the accumulation of the end products results in an increase in the rate of the reverse reaction.

7) Inhibitors : Enzyme inhibitors are of two types :

Enzyme Inhibitor

- **Reversible**
  such inhibitors are removed by dialysis
  - **Competitive inhibitors : Such inhibitors are structurally similar to the substrate molecule e.g. Malonic acid resembles with succinic acid. This effect is overcome by increasing the concentration of sucinic acid.**
  - **Non-competitive inhibitors : such inhibitors reacts with either enzyme or enzyme-substrate complex e.g. cyanides, azides**
- **Irreversible**
  Such inhibitors can not be removed because they probably alter or destruct the active sites of the enzymes.

9 Growth, Harmones & Growth regulators

Growth and Development:

Growth may be defined as a dynamic vital process which brings about a permanent change in any plant or its parts with respect to size, form, weight and volume. The permanent change may be either in positive direction or negative direction. For example, the dry weight in the sprouting potato tubers decreases during the early phase of the growth. Therefore the main points of growth are :

a) It is dynamic **vital process**.

b) It brings about a **permanent change**.

Growth

- **Primary Growth is due to**
  - **Apical meristems responsible for**
    - **Formation of Tissues**
    - **Increase in length**
    - **Differentiation of various appendages**
  - **Temporary apical meristems called Intercalary meristems responsible for increase in length in bamboo, mint etc.**
- **Secondary Growth is due to**
  - **Lateral meristems responsible for the thickness.**

Development : Development is the process of growth and differentation of individual cells into tissues, organs and organisms. It is the resultant of growth.

Phases of Growth :

Broadly there are three phases of growth :

a) The phase of **Cell Division/Cell Formation**. It is also called **Logrithmic** or **Exponential** phase.

b) The phase of **Cell Enlargement**. It is called **linear phase**.

c) The phase of **cellural differentiation** or **cell maturation**. It is also called **senscence phase**. But there are five distinct phases of growth.

1) **Lag phase** : It is the initial lag period where internal changes in the cell occur which are the preparatory to growth. Here the increase in size or weight is very slow or negligible.

2) **Log Phase** : It is the grand period of growth. Here growth is very fast.

3) **Third phase** : Here Growth rate gradually decreases.

4) **Fourth phase** : It is the phase where organism reaches to maturity and growth ceases.

5) **Final phase** : It is phase of sencence where death of organism sets in.

on the basis of the different phases of growth, a **sigmoid growth curve** (i.e. **'S' - shaped**) is obtained.

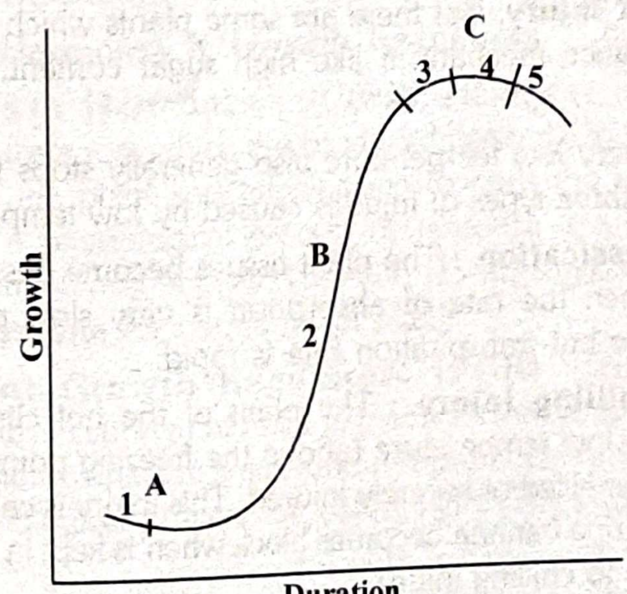


Fig. : Different Phases of Growth

The growth rate is measured in different ways by Auxanometer and crescograph (J.C. Bose).

Factors affecting Growth & Development :

Growth and Development is affected by physiological processes and environmental conditions. Absorption of water and minerals, photosynthesis, respiration etc. are the physiological processes which govern the growth and development to a very large extent. The environmental factors include the climatic factors and edaphic factors. The major two climatic factors viz Temp. and light are discussed here:

Temperature : There is a pronounced effect of temperature on the growth of the plant. Growth occurs in the range of 4°C to 45°C but the cardinal temperature range is 28-33°C. The low temperature at night reduces the rate of respiration but high temp. during the day time increases photosynthesis and accumulation of synthates which in turn increases growth. That is why **potato tubers** growing on **hills** are **much larger** than those of the plains.

The very high temperature generally stops the growth of plant by affecting many physiological processes. At high temperature, the **protein** component of the protoplasm is also **coagulated** and the protoplasm is killed. This effect of high temperature is called **heat injury**. But there are some plants which have some heat resistance mechanism like high sugar content, thick bark etc.

The very low temperature also generally stops the growth. There are three types of injuries caused by low temperature :

a) **Dessication** : The plant tissues become dessicated and injured when the rate of absorption is very slow due to low temperature but transpiration rate is rapid.

b) **Chilling Injury** : The plant of the hot climate when exposed to low temperature (above the freezing point) for some time is either killed or severely injured. This injury is called chilling injury. The ripe banana becomes black when is kept in refrigerator is only due to chilling injury.

c) **Freezing Injury** : When the plant is exposed to very low

temperature (below the freezing point), the protoplasm of the plant cell is dehydrated resulting in its coagulation due to the formation of ice crystals of water. The high concentration of the cell sap aggravates the precipitation of protein and thus resulting into the death of the cell. But there are many perennial plants which withstand the freezing injury because of the high osmotic concentration of the cell sap. Such frost resistance (or hardiness) nature of the plant lower the freezing point and reduces the amount of water.

Light : The intensity, quality and duration of light affect the growth. The weak intensity of light promotes shortening of internodes and expansion of leaves. Very weak intensity reduces the rate of overall growth. Very high intensity reduces the growth rate indirectly, increasing the water loss. Blue violet light enhances internodal growth whereas green light reduces expansion of leaves. Red colour is the most favourable light quality for growth. Beyond the visible spectrum i.e. infrared and uv-rays are detrimental for growth. The duration of light has pronounced effect on the vegetative and reproductive growth of plant. This phenomenon is called Photoperiodism which is described in the next chapter. Longer periods of light causes luxuriant vegetative growth in most of the plants. Garner and his co-workers found that the amount of vegetative growth was proportional to the duration of day light.

Growth Harmones & Growth Regulators

Growth Harmones : Growth Harmones are the such organic substances which are produced generally in meristematic tissues of the plant and translocated towards the site of action inducing a physiological process or response and can work in extremly minute quantities. Thimann (1948) suggested the term **Phytoharmone** for harmones of plants.

Plant Growth Regulators (PGR) : Such organic compounds occuring naturally in plants as well as synthetic other than nutrients which in small amounts promote, inhibit or modify any physiological process are called PGR. The PGR are of two types :

i) Growth promotor e.g. auxins, gibberellins & cytokinin.

ii) Growth inhibitors e.g. abscisic acid and ethylene.

Auxins :

1) F.W. Went (1928) isolated the growth substance which he named Auxin.
2) The plant *Avena sativa* (i.e. Oat) was used by Went for the bioassay hence the test is known as **Avena Curvature test** or **Avena Coleoptile test**. It was found that Auxin was responsible for curvature in Avena Coleoptile.
3) Thimann (1934) found that the highest concentration of auxin was occured in the coleoptile tip and a gradual decrease from the tip to the base of the coleoptile. He also noticed that the concentration of auxin was much less in the root tip than that of the coleoptile tip.
4) Auxin was a general term used to denote for such substance which promote the elongation of the coleoptile tissues.
5) Indole acetic acid (IAA) is a endogenous auxin occuring naturally in plants.
6) Synthetic auxins : Examples are -
   a) Indole – 3 – butyric acid (IBA)
   b) Indole – 3 – Propionic acid (IPA)
   c) Napthalene acetic acid (NAA)
   d) Dichlorophenoxy acetic acid (2, 4–D)
   e) Malic Hydrazide (MH)
7) MH and Acid paracoumaric have the property of anti-auxins.
8) Precursor of IAA is **Tryptophane** (produced from SKIMMIC pathway of respiration)
9) Two types of endogenous Auxin :
   a) Free Auxins : Such are utilised in various metabolism.
   b) Bound Auxins : Such auxins are attached with enzyme and/or antiauxins and therefore such are not utilised in the various metabolism. In Mango, there is no rooting even after the use of NAA. It means it is due to the presence of bound auxin.

Bound auxin means : $\left.\begin{array}{l}\text{Auxin + enzyme}\\ \text{Auxin + antiauxin}\end{array}\right\}$ checks the activity of auxin.

10) Non-Indole auxin : Example is Phenyl acetic acid found in tomato.

11) **Polar transport of Auxin** : Auxin is known for polar transport:

a) Poar transport means the movement of auxins from the morphological apex towards the base of the plant.

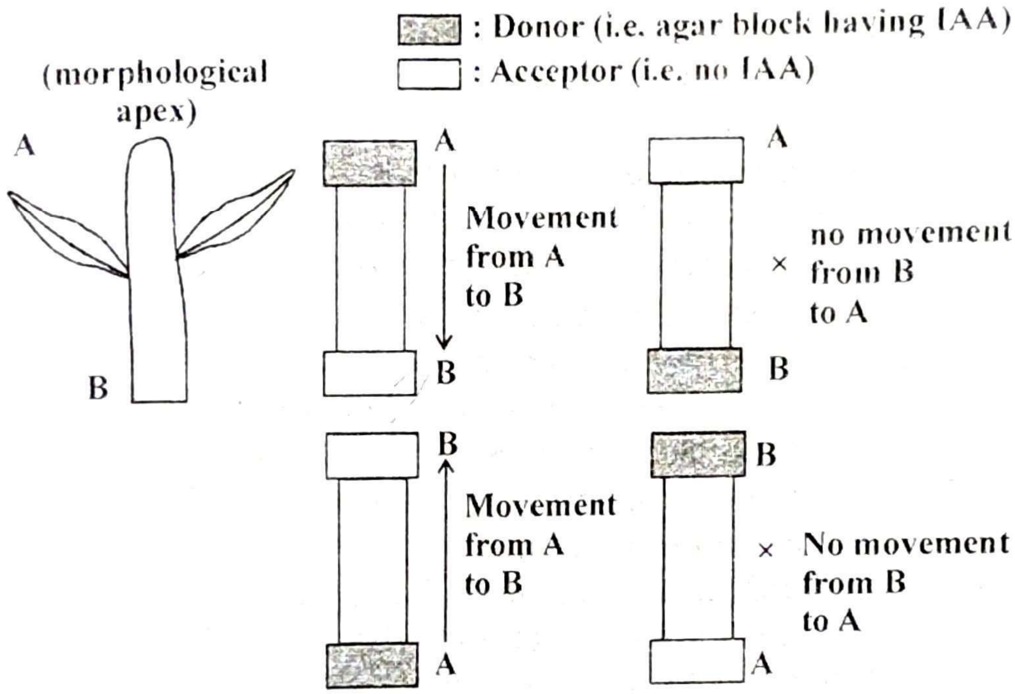


Fig. : Movement of auxin against the gradient.

b) Polar transport of IAA is strongly developed in monocot coleoptiles.

c) Polar transport is negated if anaerobic condition is maintained or treated with respiratory inhibitors. It means the movement of IAA is not polar and becomes free to move irrespective of morphological apex.

12) **Apical dominance of auxin** : The growth of the apical bud suppresses the growth of the lower axillary buds in many plants. It means the terminal (apical) bud dominants over the lateral buds by inhibiting their development. Such dominancy is called apical dominance. The development of lateral shoots or buds is inhibited by a substance which arises from the apex. When the tip of the main shoot is removed, the side shoots or buds start to develop. Thimann and Skoog (1934) found that the dominance of the terminal bud was due to the auxin.

13) Physiological Effects (Practical application) :

i) **Cell division** : Auxin is responsible for promoting cell division in certain tissues like cambium. The cambial activity and callus formation at the wounded site is stimulated by auxin. The formation of callus has practical use in grafting which strengthens the union of stock and scion. The cell division of tissue culture is entirely dependent on auxin.

ii) **Cell Elongation** : The primary physiological effect of auxin on growth of a plant is the elongation of cells. The cell elongation is activated by auxin in three ways:

a) by increasing osmotic solutes
b) by decreasing wall pressure
c) by increasing permeability of cytoplasm to water.

The avena curvature test was the bioassay for cell elongation test. But Auxin has **inhibitory** effect on **root elongation** due to the auxin-induced production of ethylene.

iii) Inhibition of Lateral buds : The sprouting of lateral buds i.e. eyes in potato tuber is checked by applying synthetic auxins. Therefore the dormancy period of tubers is increased by using IBA, NAA and MH. The opening of flower bud on fruit trees is also delayed by using synthetic auxins to avoid the damage caused by late frost.

iv) Shortening of Internodes : High concentration of α-NAA prevents the elongation of inter nodes and the plant becomes dwarf.

v) Root Initiation : Due to the polar transport of auxin, rooting starts at the morphologically lower end. Thimann & Went (1930) found that the indole acetic acid and outer growth substances were essential for initiating adventitious root formation in cuttings. For commercial use α-IBA and NAA are markedly superior to IAA.

vi) Prevention of abscission layer : The formation of abscission layers at the bases of petiole, pedicel or peduncle results into the separation of leaves, flowers and fruits from the plant. The premature drop of fruits may be stopped by spraying 2, 4-D; IAA, NAA etc.

vii) Flower initiation : Auxin generally inhibits flowering and thus is helpful in delaying the flowering in lettuce.

viii) Production of Parthenocarpic fruits : Seedless fruits are being developed by horticulturists by spraying synthetic auxins.

ix) Weed control : The roots are extremely sensitive to auxins. Auxin distorts the roots, blocks the sieve tubes and disturbs the cell division of roots. 2, 4-D is used for weed control.

Gibberellins

1) The name 'gibberellin' was used by Yabuta and Sumiki (1938) for a pure crystalline chemical which was isolated from '**Bakanae or Foolish seedling**' diseased **rice** plants. **Kurosawa** of Japan in 1926 confirmed that the disease was caused by a fungus '*Gibberella fujikoroi*' (*Fusarium heterosporum*). Due to this disease, rice plant grows abnormally thin and tall.

2) 6 gibberellins viz. GA_1, GA_2, GA_3, GA_4, GA_7, & GA_9 were isolated from the fungus Gibberella by Cross et al (1961). 3 gibberellins viz. GA_5, GA_6 & GA_8 were isolated from bean seeds by Mac Millan et al (1961). Chemically gibberellins are known as **gibberellic acid**.

3) Most commonly available gibberellic acid is GA_3.

4) Gibberellins are common in higher plants but restricted to the only certain species of Fungi & bacteria. The conc. is higher in stem apex, young leaves and seeds.

5) Gibberellins are synthesised through the normal isoprenoid pathway of terpene biosynthesis.

6) Gibberellin promotes shoot growth by accelerating the cell elongation & cell division in the **sub-apical** meristem region which increases the length of **internodes**. Gibberellin regulates the mitotic activity of the sub apical meristem.

7) In certain cases it protects the apical meristem from the inhibitory effect of **dormin** (endogenous growth inhibitor)

8) Gibberellin induces the synthesis of hydrolytic enzymes especially **protease** and **α-amylase** which triggers **seed germination**. Gibberellin is released by the seed embryo and is transported to the **aleurone** layer of endosperm where such enzymes are synthesized under its influence.

This is the example of hormonal control of enzyme synthesis.

9) Gibberellin has **no effect** on root growth and the activity of apical meristem of stem apex.

10) Physiological effects :

   i) Stem Elongation : It increases the length of internodes. It speeds up RNA-synthesis.

   ii) It converts the dwarf plant into a plant of normal height. When 'Rosette' plant of sugarbeat (example of extreme dwarfism) is treated with gibberellins, it undergoes a rapid growth or bolting.

   iii) Substituting cold treatment : Many biennials complete their life cycle within a single year by treatment with GA.

   iv) Partthenocarpic fruits : GA induces parthenocarpic development of fruits in tomato, apple & pear more effectively than auxin.

   v) Breaking dormancy : It is effective in breaking of dormancy in potato tubers and in tree buds in winter.

   vi) It promotes flowering in long day plants and induces maleness. GA introduces male flowers whereas Ethrel/ Ethephon increases femaleness.

   vii) It increases the size of leaves and fruits.

   viii) It prevents senescence.

   ix) It increases the cell division and cell size.

Cytokinin/Kinetin/Kinin

1) Jablonski and Skoog (1954) reported that the cell division in the pith cells was due to a substance present in vascular tissues. Miller et al (1956) showed that this substance was very effective in cell division. Such cell-division inducing substance is known as Kinetin and Letham (1963) used the term cytokinin (specific effect on cytokinesis) for kinetin like substances viz. Kinetenoid, Phytokinin, Phytocytomine.

2) Cytokinin is a derivative of the **purine** base **adenine** which has furfuryl substituent at the 9^{th} position which changes to 6^{th} position of the adenine ring during autoclaving of DNA.

3) At present it is clear that cytokinins are a part of t **RNA** (transfer RNA)

4) The chemical name of kinetin is N^6 furfuryl adenine or 6-furfurylamino purine.
5) Kinins promote cytokinesis in cells of various plant organs.
6) Kinetin alongwith auxin increases mitotic activity tremendously because division is promoted mainly by kinetin and auxin induces cell enlargement.
7) The endosperm of coconut (coconut milk) also contains endogenous (naturally occuring) cytokinin. **Zeatin** is endogenous cytokinin of Maize.
8) Physiological effects :
    i) It promotes cell division and the related DNA and RNA synthesis.
    ii) It has morphogenesis effect, that's why it is used for organ formation in a variety of tissue cultures.
    iii) It counteracts the apical dominance of auxin.
    iv) It is used in the breaking of dormancy. It also promotes the seed germination.
    v) It delays the phase of senescence. Senescence means the disappearance of chlorophyll and the degradation of protein. Richmond and Lang (1957) reported that the senescence was delayed in the detached xanthium leaves for several days when they were treated with kinetin. Such effect of Kinetin in retaining the senescence (ageing) is called **Richmond-Lang Effect.**

Abscisic Acid (ABA)

1) ABA is a common growth **Inhibitor.**
2) Robinson and P.F.Weiring (1963-64) extracted the inhibitory substance and called it '**dormin**' because it caused dormancy.
3) Okhuma et al (1963, 65) isolated the very active inhibitor from young cotton fruits and called it abscisin II. Abscisin I was isolated from the burrs of mature cotton fruits. Later on in 1967 it was realised that the dormin and abscisin II were the same and was named Abscisic acid (ABA).
4) Physiological Effects :
    i) It accelerates the senescence phase of growth.
    ii) It regulates the buds and seeds dormancy by inhibiting the growth processes.

iii) It inhibits GA-induced α-amylase synthesis thus inhibiting germination of seeds.
iv) It inhibits gibberllin - stimulated growth hence called **antigibberellin.**
v) It causes abscission of leaves.
vi) It inhibits RNA and Protein synthesis.
vii) It causes the closure of stomata by interferring with the uptake of K^+ (Na^+) in guard cells.

Ethylene

1) Ethylene ($CH_2 = CH_2$) is a volatile gas which is included under Hormones in 1971.
2) It is synthesized in plant from the amino acid Methionine.
3) The most important effect is fruit **ripening** (**climacteric rise of respiration**). The climacteric rise indicates the beginning of senescence and death.
4) Ethylene increase the cell permeability due of which the fruit becomes soft.
5) The inhibitory effect of auxin on root elongation and buds growth is due to auxin-induced production of ethylene.
6) High concentration of CO_2 i.e. 5-10% inhibits the effect of ethylene. Ag^+ is also the inhibitor of ethylene action.
7) According to D.N. Neljubow, ethylene caused triple response on Pea seedling :
   i) It inhibits stem elongation
   ii) It increased stem thickening.
   iii) It stimulated horizontal growth habit.
8) Ethrel/Ethephon : The chemical which releases ethylene.
9) **Physiological effects:**
   i) It induces climacteric rise and fruit ripening.
   ii) Induction of epinasty (leaf bending), leaf abscission and stem swelling.
   iii) Inhibition of stem and root growth.
   iv) Induction of flower petal discolouration.

Difference between Growth Inhibitor and Growth retardant

Growth Inhibitor	Growth Retardant
1) Such are the chemicals which inhibit or retard physiological or biochemical processes in plants.	1) Such chemicals retard cell-division and cell elongation in shoot tissues and thus regulate the plant height.
2) It causes malformation of leaves and stems.	2) There is no malformation.
3) It completly suppresses the plant growth.	3) Does not completely suppress.
4) It causes yellowing and abscission of leaves.	4) It intensifies the green colour of leaves.
5) It affects the vigour and rate of organ development.	5) There is no such effect.
6) Examples : i) Malic Hydrazide (MH) ii) ABA	6) Examples : i) Cycocel or CCC or chlormequant ii) Phosphon D iii) Amo-1618 etc.
7) It may be antigibberellin, antiauxin, antigermination	7) It is mainly antigibberellin.

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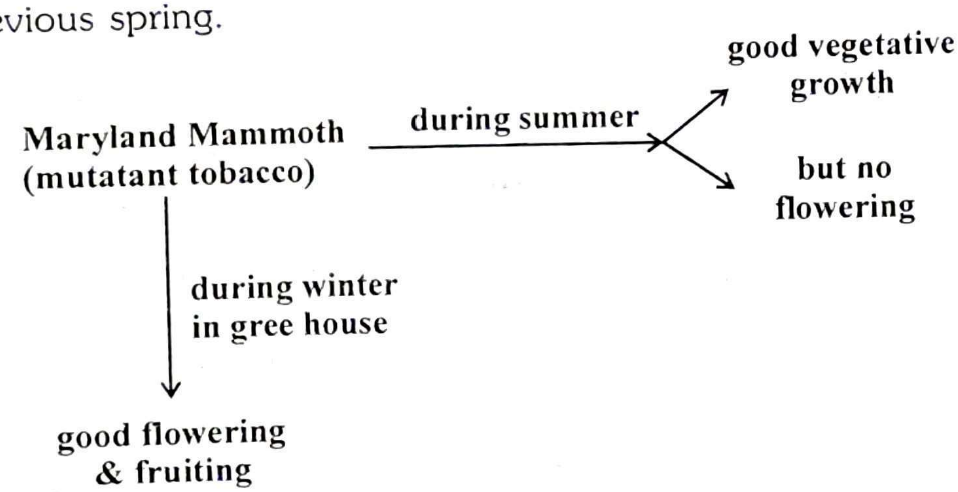
10 Photoperiodism and Vernalisation

The maturity of vegetative growth of the plant proceeds flower initiation. But the flower initiation of flowering depends on the environment specially light period (photo period) and temperature (vernalisation).

Photoperiodism

Photoperiodism is the physiological response of plants to relative length of light (day) and dark (night) periods. W.W. Garner and H.A. Allard (America, 1915-20) found that a newly developed ***tobacco mutant, Maryland Mammoth*** and Soybeans (*Glycine max*) had strange seasonal pattern in flowering. Maryland Mammoth did not flower during summer but had good vegetative growth. When it was grown within a green-house during winter, it had excellent flowering and fruiting. Similarly soybean flowered only in the late summer irrespective of the sowing time in the previous spring.



The term 'photoperiodism' was coined by **Garner** and **Allard** (1920) to disignate the response of organisms to the relative length of the day and night and the 'photoperiod' to disignate the favourable length of day for each plant. They classified the plants into three groups according to their photoperiods:

a) Short day plants : Such plants require to flower the day-length less than the certain critical day-length (for say 12 hours). Such plants are also called **Long night plants** because for its flowering a certain minimum uninterrupted dark period in 24 hours is necessary. If the dark period is less than a critical length, there will be no flowering. Short day plants will not flower if the dark period is interrupted by a flash of light during the continuous dark period but such light interruption is not very effective if it is given near the beginning or the end of the dark period. Such plants don't also flower if short dark and short light periods are provided alternatively. Examples of short day plants are **Maryland Mammoth tobacco, Soybean, Chrysanthemum, Rice,** *Chenopodium album, Xanthium stumarium* (cocklebur), Generally Kharif crops and many tropical plants.

b) Long day Plants : Such plants which flower only when the day length is longer than a certain critical period. The ciritical length varies from 4 to over 18 hours. They require either a relatively small period of darkness or no darkness at all. A flash of light to long day plants during long dark period can induce flowering even during short day period. This is called **Night break**. Here, darkness has an inhibitory effect on flowering. The flowering in long-day plants is inhibited not because of the short light periods but because of too long dark period. That's why such plants are also called **short night plants**. e.g. Wheat, barley, oat, sugarbeet, spinach, lettuce, castor, generally rabi crops.

c) Day neutral plants : Such plants are unaffected by the day-length e.g. **Maize**, **tomato**, **sunflower**, **cotton**, cucumber, balsam etc.

Critical Period : It is the photoperiod required to induced flowering e.g. for M.M.tobacco, critical day period (CDP) is 12 hours and for xanthium it is 15.5 hours.

Photoperiodic Induction : In short day and long day plants, a continuous favourable photoperiod till blossoming is not essential but a few days' exposure to the appropriate photoperiod is enough to induce flowering. This photoperiodic influence

persists even when a treated plant is kept in unfavourable photoperiods. This initial important effect on flowering is known as photoperiodic induction or photo-induction.

Flowering Stimulus : Cajlachjan (Cailakhyan) while working on chrysanthemum and perilla demonstrated that the photoperiodic stimulus was perceived by the leaves of a plant. Garner and Allard found that the stimulus was highly localised or systemic. Even if a single leaf of cocklebur was exposed to short days and the rest of the plant to long days, flowering was occured in the whole plant. It means that this stimulus is systemic.

Mature leaves are very sensitive to the photoperiodic stimulus while very young and old leaves are generally insensitive. Green colour of light spectrum is normally ineffective in inducing flowering whereas blue colour induces poor flowering. It is the **red** spectrum (wavelength of 580 nm to 680 nm) of light which is the most effective for inducing flowering in both short day and long day plants.

Cajlachjan (Chailakhyan) used the term **Florigen** for a flowering stimulus hormone. Formation of florigen is triggered by **phytochrome**.

Dr. S.M. Sircar (Bose Institute) induced flowering of a winter variety (Aman) of rice in 50 days against normal 140 days.

Vernalisation

In annual plants the flowering is primarily affected by the photo period but in biennials flowering requires prolonged periods of low temperature. The effect of temperature is secondary to light. Firstly G.Gassner of Germany (1918) reported the effect of temperature on reproductive development. 'Vernal' means spring.

The term 'Vernalisation' was coined by T.D. Lysenko (1920).

The Russian term 'Jarovizacija' means pre-sowing treatment.

Gassner demonstrated his experiment on winter Petkus rye (*Secale cereale cv. petkus*). The low temperature requirement of winter petkus rye was given by chilling treatment. The imbibed seeds (water soaked) were stored at 2-5°C for 5-6 weeks and then was sown in the spring season. Flowering was occured on the same schedule as on spring cultivar of petkus rye flowered.

Summary of Experiment :

$$\text{Winter Petkus rye} \xrightarrow{\text{Chilling treatment}} \text{Spring Petkus rye}$$

means winter variety is vernalised.

Cold treatment is quantitative or facultative (means low temp. results in faster flowering) but not qualitative or absolute (qualitative means flowering absolutely depends upon cold)

Vernalisation is the cold treatment to a plant bud or seedling in order to fulfil a specific low temperature rquirement for accelerating the flowering. In other words the acquisition or hastening of the ability to flower by chilling treatment is called vernalization or yarovization (Russian term)

Site of Vernalisation : growing point (apical buds)/early stages of germination/embryo undergoing rapid cell division/ initiating metabolic process in shoot/meristematic zones.

It means that dividing cells are the site of vernalisation.

Cause : The growth substance formed by low temp. induction was named 'vernalin' by G.Melchers (1939).

According to Mikhail Chailakhyan (1968) there were two substances responsible for vernalisation :

i) Gibberellin or gibberellin like substances

ii) Anthesin.

Devernalization : Vernalization effect is reversible. If the vernalized seed or plant is kept at high temperature just after vernalisation, the effect of the low temp. treatment is compeletely removed. This process is called devernalisation.

$$\text{Vernalised seeds or plants} \xrightarrow[(\geqslant 30^{\circ}C)]{\text{High temp.}} \text{Normal or Original seeds/plants}$$

Factors of Devernalization :

$$\left.\begin{array}{l}\text{a) High temp.}\\ \text{b) Anaerobic condition}\end{array}\right\}\begin{array}{l}\text{just after}\\ \text{vernalization}\end{array}$$

Pratical benefits :

1) To induce earlier flowering and earlier maturity of crop.

2) To escape frost, drought and flood.

3) To extend cultivation to the region with very low temp.

with very low temperature (extensively used in Russia i.e. Siberia where only 2 months are ice free for growing early crops.)

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11 Agricultural Entomology An Introduction

1. INSECT–PEST : Pest is a Latin and French word meaning plague or infectious disease. Earlier the term 'pest' was used for devastating infectious disease. But today the 'pest' is defined as "such an insect or any other living being whose population increases to such an extent to cause economic losses to crops or a nuisance and health hazard to man and his livestock."

Criteria of to be pest : From the above definition we derive three criteria of pest –

(a) Insect or any other living organism

(b) Economic losses to crop or human health.

(c) A minimum population level i.e. Threshold level of population.

It means to control insect-pest below the threshold level of population has no significance. Therefore pest control measures are to be adopted at threshold level (or economic level) i.e. before the Economic Injury Level.

Threshold Level ⟶ Control ⟶ Economy Injury
Or (TL) Level
Economy Level (EIL)
(EL or ETL)

Economic Threshold Level (ETL or TL) : Economic Threshold (ET) is the density of the pest population which needs control measures. According to Stern et. al (1959) : ETL is the pest density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level (EIL).

Economic Injury Level (EIL) : Stern et. al (1959) defined it as the 'Lowest population density that will cause

economic damage." Headley (1972) defined as the "pest population that produces incremental damage equal to the cost of preventing damage."

Conclusion : (1) All insects are not Pests.
(2) All pests are not insects.
(3) Pest may be insect, nematode, mite, fungus, bacterium, virus, rodent etc.

2. Entomology :

Entomo + Logos ⟶ Greek words
↓ Means ↓ Means
Insect discourse
↓ Means
Cut into (Section)

3. Phyllum : Arthropoda

Anthros + Podus ⟶ Greek words
↓ ↓
Segmented Leg

Class : Hexapoda : Body is divided into three parts viz. Head, Thorax and Abdomen. It has three (3) pairs (i.e. 6 legs) of legs. Wings are present. Examples are Insects, Bugs, Beetles. Insects are 97% of total population of Arthropoda. Arthropoda having 94000 species is the largest group.

Class : Arachnida : Head and Thorax are fused and known as cephalothorax. Four (4) pairs (i.e. 8 legs) of walking legs are present and Legs are unsegmented. Abodomen is distinct. It has ***no*** antenna. Examples : Mites, Ticks, Red spider.

4. Insects :

Insects are :

(a) Tracheate Arthrophods means having trachea for respiration.
(b) Head, Thorax and abdomen are distinctly present.

Insect = Head + Thorax + Abdomen
↓ ↓ ↓
Usually 6 segments **Fused** | 3 segment distinct | 11 segments distinct

Abdomen has main function of ***Respiration*** and ***Reproduction.***

(c) 3 Pairs of working legs are present on Thorax. It means Thorax has main function of Locomotion But one pair (2 only) of trachea also on thorax therefore it has minor function of respiration. Remaining trachea are on Abdomen.

(d) 1-2 pairs of wings are present.

(e) One pair of antennae present.

5. Ticks/Mites :

Acarina; no antenna; no wing; 4 pairs (8) of legs; Number of spiracles → 4 (maximum); Mouth parts → Piercing type; Head and thorax are fused and fixed. Killing substance of Acarina is called acaricide.

6. Metamorphosis :

Metamorphosis is the radial changes in morphology during development. It may be incomplete or complete.

(a) Incomplete/Direct/Gradual/Hemi-Metamorphosis : Here metamorphosis occurs in three stages :

Egg → Nymph → Adult

Here Egg is turned into nymph during the development but nymph is the smallest form of an adult; therefore such metamorphosis is called Direct metamorphosis. Such types of gradual metamorphosis are present in following orders:

(i) Orthoptera : e.g. Locust, Grasshopper, Cockroach
(ii) Thysanoptera : e.g. Thrips
(iii) Isoptera : e.g. Termites
(iv) Heteroptera : e.g. True bugs
(v) Homoptera : e.g. Aphids, Leaf hoppers

(b) Complete/Complex/indirect/Holometamorphosis : Here radial changes in morphology occur in four phases i.e.

Egg ⟶ Larva ⟶ Pupa (Cocoon) ⟶ Adult

Examples of such complete metamorphosis are in :

(i) Coleoptera : e.g. Beetles, Weevils. This order is most damaging.

(ii) Lepidoptera : e.g. Moths, Butterflies, Silkworm

(iii) Diptera : e.g. Flies.

(iv) Hymenoptera : e.g. Sawflies, Bees, Ants, Wasps, (Mostly insects are used as Predators)

Some early order i.e. Protura & Thysanura of class Insecta have no any metamorphosis and are characterized as **Ametabola** e.g. Apterigola.

Types of Larvae : Larva is of 4 types :

(a) Nymph : e.g. Order-Hemiptera ; Bugs, Hoppers, Whiteflies, Aphids, Jassids.

(b) Caterpillar : e.g. Lepidoptera; Moth, Bollworm, Borer (Except lesser grain borer)

(c) Grub : e.g. Coleoptera and Mustard Sawfly (Hymenoptera)

(d) Maggot : e.g. Diptera [all flies except white fly and mustard Sawfly (MSF)]

7. Mouth Parts and its types :

Mouth parts of an insect :

(a) Maxilla : It cuts the food material i.e. cutting of Food.

(b) Mandible : It crushes the food material i.e. crushing of food.

(c) Labium : It acts like lower lip.

(d) Labrum : It acts like upper lip.

Labium and Labrum saves the food material from to come out from mouth.

(e) Hypopharynx : It works like Tongue. It mixes the crushed and cut food material.

Types of mouth parts :

(i) Piercing and sucking Type : e.g. Mosquito, aphids, bugs, Leafhoppers.

(ii) Sponging Type : e.g. Housefly.

(iii) Siphoning Type : e.g. Butterfly, Moth (simple sucking type)

(iv) Rasping and Lapping Type : e.g. Honey bee
or
chewing and lapping type)

According to agricultural purpose, there are two types of mouth parts of insect :

(a) Chewing/Biting and cutting type : Insects having such type of mouth parts are controlled by stomach poison. Such pests are generally called chewing pests. Examples are : Grasshoppers, Larvae (all), Locust, Cricket, Beetles & Weevils.

(b) Piercing and sucking type : It is also of two types viz. Bug type and (ii) Mosquito type. Such insects are controlled by systemic or contact poison and are generally called piercing and sucking pests. Examples : Bugs, Plant hoppers (except grass hopper), Aphids, Jassids, Thrips.

8. Damaging Stages :

Insect-pests have some damaging stages in its life cycle which cause losses to plants and trees :

Orders		Damaging stage
(a) Coleoptera	:	Larvae (grub) + Adult both stages
(b) Lepidoptera	:	Only Larvae (Caterpillar) Except Fruit sucking moth (FSM). Adult stage of Fruit sucking moth causes damage.
(c) Hemiptera	:	Nymph + Adult both stages
(d) Diptera :		Generally parasites
(e) Hymenoptera	:	Except Mustard Sawfly, all others are beneficial and used as biological control agents.

9. Bhopal Gas Tragedy :

This mishappening was occurred on 3rd Dec. 1984 in Union Carbide of India at Bhopal. This company manufactures Methyl Isocyanate which is used in the production of Carbaryl.

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12 Insecticides

The Chemical or poison used to kill the insect is known as Insecticide. To control the harmful effect of Insecticides on human and other living beings, a regulatory act was enacted on 2nd September 1968 by Govt. of India. This Insecticide Act regulates the use, production, sale, import, transportation and distribution of insecticides.

1. Mode of Action of Insecticides : Broadly four types of insecticides are characterized on the basis of the effect of insecticides :

(a) Systemic poison : Such type of chemicals or poisons are absorbed into plants and translocated to whole plant system internally. Such poisons are translocated and concentrated more in the aerial part of plant. Insect Pest starts dieing when it sucks the affected plant juice. This poison affects the metabolism of sucking insect pests. It means systemic insecticides are used to control sucking pests. Examples of systemic insecticides are : $DRM^2 PACT^2$

Where, D → Dicrotophos
R → Rogor (Dimethoate)
M → Metasystox and Systox (Methyl demeton and demeton)
M → Monocrotophos (Nuvacron)
P → Phosphomidon (Dimecron)
A → Aldicarb (Temik)
C → Carbofuran (Furadan)
T → Thimet (Phorate)
T → Thionazin (Zinophos)

All the above systemic insecticides are either organo-phosphates or carbamates.

(b) Contact poison : The poison brings about death of

the insect pest by means of contact, is called contact poison. When such chemical comes in contact with the pest, it penetrates into the body through the vulnerable sites, viz. sutures, trachea. Examples:

Malathion (Organophosphate), Monocrotophos (Organophosphate), Diazinon (Organophosphate), Thiodan (chlorinated), carbaryl (carbamate) Baygon (Carbamate)

(c) Stomach poison : Such chemical causes the death of insect only when the insect feeds on the treated plant. This poison acts on the digestive system of insect when ingested. Stomach poison is used mainly to control chewing type insects. Toxaphene is basically a stomach poison.

Cholorinated Insecticides are generally both stomach + contact poisons. Examples :

HECDAQ

Where,

H → Heptachlor
E → Endosulfan (Thiodan)
C → Chlordane
D → DDT
A → Aldrin
Q → Quinolphos (Organophosphate group)

(d) Fumigant : Such chemical enters in gaseous form through respiratory system (trachea) and kills the pest. It is used to control all types of insects irrespective of its feeding habits. E.g. Aluminium phosphide.

Table : Insecticides and their trade names

Insecticides	**Trade names**
Organochlorines	
Dicofol 18.5 EC (miticide)	Kelthane
Endosulfan 35EC	Thiodan
Organophosphates	
Acephate 75% SP	Asataf, Orthene and Starthene
Chlorpyrifos 20EC	Dursban

...by means of contact is called contact poison.
...insecticide comes in contact with the pest. It penetrates
...through the integument, viz. sutures, setae...

...(Organophosphates), Monocrotophos
...ovan, Diazinon (Organophosphates), Thiodan
...carbamate) carbamate, Baygon (Carbamate)

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...Insecticides and their trade names

...ides	Trade names
...lorines	
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...an 35EC	Thiodan
...osphates	
...5SP	Asataf, Orthene and Starthene
...os 20EC	Dursban
Dimethoate 30EC	Rogor
Dichlorvos 76EC	Nuvan, Vapona
Ethion 50EC	Fosmite
Fenitrothion 50EC	Sumithion
Monocrotophos 36SL	Nuvacron
Malathion 50EC	Cythion, Hilthion
Methyl parathion 50EC	Metacid
Oxydemeton-methyl 25EC	Metasystox
Phorate 10G	Thimet
Phosphamidon 40SL	Dimecron
Phosalone 35EC	Zolone
Profenophos 50EC	Curacron
Triazophos 40EC and 20EC	Hostathion
Quinalphos 25EC	Ekalux
Carbamates	
Aldicarb 10G	Temik
Carbofuran 3G	Furadan
Carbaryl 75WP	Sevin
Methomyl 40SP	Lannate
Propoxur 1% Aerosol	Baygon
Thiodicarb 75WP	Larvin
Synthetic pyrethroids	
Betacyfluthrin 2.45 SC	Bulldock
Bifenthrin 10EC	Talstar
Cypermethrin 10EC & 25EC	Cymbush, Ripcord
Deltamethrin	Decis 2.8EC, K-Othrin 2.5WP
Etofenprox 10EC	Trebon
Fenpropathrin 10EC	Meothrin
Fenvalerate 20EC and 0.4% DP	Fenval
Alphamethrin 10EC	Alphaguard
Fumigant	
Aluminium phosphide (Tablets or pellets)	Celphos

New insecticides group	
Neonicotinoids	
Imidacloprid	
As spray liquid	Confidor 17.8 SL
WP formulation	Gaucho 70WS
(Seed treatment)	
Thiamethoxam	
Wettable Powder	Cruiser 25WG
Spray liquid	Actara 70 WS
Acetmiprid 20 SP	Pride
Pyyrole insecticides	
Fipronil 5 SC	Regent
Avermectins	
Emamectin benzoate	Proclaim
Spinosyns	
Spinosad 45% SC and 2.5% SC	Tracer, Naturalyte
Chitin synthesis inhibitors	
Diflubenzuron 25WP	Dimilin
Biopesticides	
Bacillus thuringiensis (Liquid and WP formulations)	Dipel, Delfin, Halt, Spicturin, Biolep, Biobit
Verticillium lecanii	Vertilec
Beauveria bassiana	Larvocel, Boverin
Hirsutella thompsoni	Mycar
Metarrhizium anisopliae	Biomax
NPV	Elcar
Miscellaneous	
Cartap hydrochloride 4% Granules and 50SP	Padan, Caldan

[A] Inorganic Compounds :

(i) Paris green (double salt of copper arsenite and copper acetate) was firstly used as insecticide by about 1867 to control colorado potato beetle.

(ii) Lead arsenate was used first in 1832 by Moulton to control gypsy moth in Massachusetts.

(iii) Calcium arseinate was first used by about 1906 to control leaf eating insects.

(iv) Sodium fluoaluminate (sodium aluminium fluoride) was used first in 1929 by Marcovitch and Stanely to control chewing insects.

(v) Lime sulphur was used first as a fungicide in 1852 by Grison and later in 1886 by Dusey to control San Jose Scale. Sulphur is primarily a fungicide and acaricide.

(vi) Borax (sodium tetraborate) is used to control fly maggot in manure pits and animal wounds infested by maggots.

(vii) Zinc phosphide (Zn_3P_2) is a well known rat poison. Zinc phosphide when ingested into the rodent's stomach, reacts with hydrochloric acid of stomach and releases phosphine gas which is extremely reactive and poisonous.

Other inorganics used as insecticides and pesticides are sodium fluoride, white arsenic, Barium carbonate, Thallium sulphate etc. Inorganics are stomach poison.

[B] Organic Compounds :

I. Hydrocarbon Oils : e.g. coal tar oil, mineral oil. Anthracnose oil is used for wood preservation. The phytotoxic nature of oils is due to presence of unstable unsaturated compounds. The mineral oils or the petroleum oils are derived from sedimentary rocks.

II. Animal origin compounds : The insecticide Nereistoxin is obtained from marine annelids *Lumbrineris* (Lumbriconeris) *heteropoda* and *L. brevicirra.*

III. Plant Origin Compounds/Botanical Compounds:

(i) Nicotinoid/Nicotine : It's main source is *Tobacco.* Nicotine shares 0.5 – 5.5% and 3.5 – 8.0% in the leaves of *Nicotiana tabacum* and *N. rustica* respectively. The scientific study of insecticidal property of Nicotine alkaloid present in tobacco leaves was made first time in 1828 by Passlet and Reimann. The structure of Nicotine was confirmed in 1893 : 1-3 (1-methyl – 2- Pyrrolidyl) pyridine.

Nicotine is a contact and nerve poison which affects especially soft bodied insects. It's main effect is on aphids and thus prior to the use of synthetic insecticides it was known as ***aphicide***. It has no phyto-toxic and residuary effect, that's why the sprayed crops may be harvested just after two days. But for the mammals, it is highly toxic. It is marketed in the name of Nicotine sulphate. Due to high volatization rate, it may be used as fumigation in the glass-house. Dust formulation of nicotine sulphate releases nicotine in the presence of moisture.

(ii) Pyrethroids/Pyrethrins/Pyrethrum: Source: White flowers of *Chrysanthemum cinerariefolium* (Guldaodi) In the beginning of the 19th centuary (1800-1899) Jumtikoff of Armenia found that the tribals of the Caucasus (the area between the Caspian sea and black sea) were using the flower dust of chrysanthemum spp. Generally the mixed esters of Pyrethrolone and Cinerolone are called pyrethroids/ Pyrethrins in which 0.7 to 3% is chrysanthemic and Pyrethric acids. Since these esters can't be separated, therefore it is collectively called Pyrethrins. Pyrethrins are powerful contact insecticides which rapidly paralysed the housefly. This characteristic action is known as ***"knock down"*** effect. It is extremely unstable hence it is of little value for field crops. Pyrethrum is used with the solvent of DDT e.g. Flint. Here DDT acts like synergist which increases the action of pyrethrins. The equivalent synthesized compounds of pyrethrins are Allethrin, Cypermethrin, Dimethrin and Barthrin which are harmless to man.

(iii) Rotenoids/Rotenone : Source : Roots of leguminous plants *Lonchocarpus* spp (South American plant) and *Derris eliptica* (Malaysia). Insects poisoned with rotenone show a steady decline in oxygen consumption followed by paralysis and death. It is well known contact fish poison. It was first used in 1848 against leaf eating caterpillars. However rotenone was first isolated in 1895 by Geoffrey. It is used as dust containing 0.75 –

1.5% rotenone and effective against beetle and caterpillars.

(iv) Raynia/Ryanodine : It is an alkaloid derived from ground roots and woody stems of south American shrub. *Ryania spaciosa* (family–Flacourtaceae). It is a stomach and contact poison and effective against Lepidopterous pests. It is a muscular poison and known for blocking the conversion of ADP to ATP in striated muscles. It is used as dust (20-40%).

(v) Sabadilla : It is an alkaloid derived from seeds of tropical lily *Schoenocaulon officinale* (Family : Liliaceae) found in South and Central America. The alkaloids mainly cevadine and veratridine are contact poison and used for the control of houseflies and domestic insects. It is harmful to pollinators honeybees.

(vi) Margosa (Neem)/Azadirachta indica : Kernels of the neem tree *(Azadirachta indica)* posses extraordinary gustatory repellant properties which are attributed to the active ingredients nimbidin-T, meliantriol and azadirachtin. The main a.i. azadirachtin is present in seeds and leaves and varies from 2-4 mg/g Kernel. Neem is known for various insecticidal properties e.g. antifeedant action, insect growth regulatory activity inhibits juvenile harmone synthesis, Oviposition deterrent, repellant action, reduction of life span of adultsand intermediates. Insecticide vapacide is prepared from neem cake. The commercial neem insecticides available in market are based on neem seed kernel extract (NSKE). Some products are Gronim, Neemazal, Achook, Nimbecedine. Neem based products are sensitive to UV light i.e. it degrades when exposed to sunlight.

Some another botanicals are yet to be used on large scale :

(vii) Limonene and Linanool are citrus peel extracts which cause insect paralysis. They evaporates quickly in environment hence are used to control aphids, mites and fleas.

(viii) Garlic oil due to presence of diallyl disulfide and diallyl trisulfide shows larvicidal property and is fatal to larvae of mosquito *Culex pipiens quinquefasciatus.*

(ix) Root diffusates of the crucifers *Brassica nigra* and *Sinapis alba* inhibit emergence of the golden cyst nematode of potato *(Globodera rostochiens)* due to the presence of isothiocyanates. Thiophenic compounds present in Tagetes sp. suppress the population of *Meloidogyne, Pratylenchus penetrans* etc. Root extracts of *Asparagus racemosus* inhibits hatching of eggs of *Meloidogyne javanica* and *M. arenaria.* Tannin and polyphenols found in aqueous extracts of raspberry roots and canes *(Rubus ideaus)* are poisonous to the nematode *Longidorus elongatus.*

IV. Synthetic Organic Compounds :

Such organic compounds may be broadly grouped into Organochlorines, organo-phosphorus compounds, Carbamates Dinitrophenols.

[A] Chlorinated Hydrocarbons :

(1) DDT : $C_{14}H_9Cl_5$

DDT → Dichloro Diphenyl Trichloroethane but chemical name of DDT is

p 2–bis (p-chlorophenyl) 1,1,1 – trichloroethane (old)
2,2–bis (p-chlorophenyl)–1,1 trichloroethane (new)

DDT is a mixture of two isomers viz pp'–DDT (>80%) and op'**–DDT.** DDT was first synthesized by Othmar ***Ziedler*** in 1874 but its insecticidal property was first discovered by **Paul Herman *Muller*** of Ciba Giegy Company in 1939. Muller obtained Swiss patent in 1942 for his discovery and awarded Nobel prize in Medicine in 1942. This Insecticide was used on the large scale first time during World War II in 1942 by the Allied Troops in Naples, Italy. It was discovered as first protective insecticide. It is a stomach and contact poison. It is one of the most apolar compounds and practically insoluble in water. pp' – DDT is more toxic than op' – DDT. DDT poisoned

insects show tremors throughout the body and the appendages, characteristically called ***"DDT Jitters"***. Its use in agricultural sector has been withdrawn in India and permitted to be used only for mosquito control under public health programme as 50% WP or 75% WP.

DDT Analogs :

* Rhothane (trade name) is a contact & stomach poison.
* Methoxychlor is easily biodegradable and has faster knock down of houseflies.
* Dicofol (Kelthane) is effective as acaricide and used presently for control of mites. It is effective for all stages of mites, harmless of bees and possesses long residual effect. Its acaricidal properties were first discovered by -J.S. Barker and F.B. Maugham in 1956.
* Acaricides like DMC (Dimite) and Chlorobenzilate are another DDT analogs.

3. BHC/HCH :

Benzene Hexachloride/666/Gammexane

Benzene Hexachloro Cyclohexane.

$C_6H_6Cl_6$: 1, 2, 3, 4, 5, 6 –hexachlorocyclohexane (i.e. HCH). The HCH compound was first synthesized in 1825 by Michael Faraday but its insecticidal properties were rediscovered between 1940-1942. HCH has 6-isomers but γ–isomer (Gamma-BHC) is highly active for insecticidal property. The composition of isomers in BHC :

(i)	alpha	(α)	–	55-70%
(ii)	Beta	(β)	–	5 – 14%
(iii)	Gamma	(γ)	–	10-18%
(iv)	Delta	(δ)	–	6% - 7%
(v)	Epsilon		–	3-4%
(vi)	Eta		–	in trace

A German chemist Van der Linden discovered four isomers of BHC in 1912. The toxic γ-isomer was isolated by British group of scientists and named it *Lindane (Gammexane)* in honour of van der Linden. Toxicity of BHC is proportional to the toxic content of γ-isomer. The prepared product Lindanc contains *at*

least i.e. a minimum of 99% *γ-isomers*. It is a stomach and contact poison and has fumigant action.

Since Lindane dechlorinates in normal alkali condition, therefore it is not used in alkali soil. It should not be sprayed on vegetable, roots, tuber crops and fruits otherwise it may have harmful effect. Hovever it is not harmful for the crops but may damage the primary growth stage of cucurbits. There must be a gap of two weeks between harvesting and spraying on crops. It is used to control soil insects and ectoparasites and it has long residue in the soil.

3. Cyclodiene Insecticides : Such are highly chlorinated cyclic hydrocarbons having 'endomethylene bridged' structure. The toxicity of these insecticides is due to its high lipoid solubility such insecticides are:

3a. Chlordane : $C_{10}H_6Cl_3$ – Its insecticidal property was described firstly in 1945 by Kearns et al. It is a presitent (stomch + contact) poison and light fumigant. It is especially effective against soil insects and termites. It should not be used on leafy vegetables. It becomes non-poisonous due to alkaline dehydrochlorination. That's why it is not kept in Zinc containers or galvanized containers. Its use in India is withdrawn.

3b. Heptachlor : $C_{10}H_5Cl_7$ – It was introduced in 1948. It is (contact + stomach) poison and has some fumigant property also. It is 4-5 times more effective than chlordane. It may be used for seed treatment and soil treatment. It has no residual effect. It has no harmful effect on leafy vegetables. Therefore it is used on agricultural and horticultural plants. It is generally compatible for all insecticides and fungicides. But now a days its use in India has been withdrawn.

3c. Aldrin : $C_{12}H_8Cl_6$: The insecticidal properties were firstly described by C.W. Kearns et. al. in 1949. It is named after the German chemist Kurt Alder who received the Nobel prize in chemistry in 1950 for his work on diene synthesis used in formulation of cyclodiene insecticides. It is a persistent stomach + contact poison which is used against soil insects. The epoxidised conversion of Aldrin into Dieldrin ($C_{12}H_8Cl_6O$) in

soil is highly persistent but Aldrin itself is not persistent. Therefore it has limited use. In alkali soils Aldrin is used instead of γ-BHC or lindane. It's use is also withdrawn in India. In India Dieldrin is only used for locust control. Endrin is banned in India which is an isomer of Dieldrin.

3d. Endosulfan (Thiodan) : $C_9H_6Cl_6O_3S$: It is an insecticide of Sulphite group. The insecticidal properties were firstly described by W. Finkenbrink in 1956. It is a contact + stomach insecticide and has slight fumigant action. It is practically soluble in water, persistent and non-volatile. It is used in the form of spray and its general formulation is 35% EC. Due to high toxicity, the sprayed crop may be harvested after at least six weeks gap. Due to its harmful effect, the state govt. of Keral banned it in July 2002.

[B] Organo-phosphorus compounds :

The insecticidal properties of Organo-phosphates were firstly discovered by Gerhard Schrader (chemist) in 1939. He found that some poisonous compounds were absorbed through the plant leaves or roots and were diffused into the whole parts and thus the plant escaped from the insect attack due to poisoned sap. The one such compound was Octamethyl Pyrophosphora mide (OMPA/Schradan). Schrader developed Tetraethyl pyrophosphate (TEPP) as a substitute for nicotine. The insecticide detoxified into the plant due to enzymes of plant.

Cholinesterase, an enzyme, is an essential constituent of the nervous system in both insects and higher animals. The Organo-phosphate phosphorylate the active site of this enzyme and such phosphorylated enzyme is an irreversible inhibitor which inhibits the normal process of quick removal and distruction of neurohormane acetylcholine (Ach) from nerve impulse resulting into the accumulation of acetylcholine and therefore the normal process of Nervous system is disrupted. Such Organophosphate as a nerve poison was firstly systhesized during the first world war.

Before the spraying of any systemic organophosphate one should verify the sufficient moisture into the soil. The deficiency

of soil moisture causes the accumulation of active ingredient (a.i.) on the leaf margin which may result into margin burn or Necrosis. Most of the Chlorinated insecticides can be stored for a longer period but Organo-phosphate for the shorter period.

Organophosphate has certain advantages such as rapid action against a wide spectrum of pests, low persistence, breakdown to form products non-toxic to man & animals, low dosages required per unit area, comparatively low mammalian toxicity and relatively thick metabolism in vertebrates and absence of accumulation in their bodies. Organo-phosphates are successful insecticides.

[B_1] Phosphomidon (Dimecron) :

It is a systemic insecticide since it is highly soluble in water, it is suitable for low volume and Ultra low volume spray (LVS/ULVS). In alkaline medium, its insecticidal property is reduced due to rapid hydrolysis. Therefore it is not sprayed along with such fungicides like Bordeaux Mixture, Lime Sulphur, Nicotine Sulphate and Copper Oxychloride. It was first synthesized in 1955 by E. Beriger of CIBA but its insecticidal properties were described in 1956 by F. Bachmann and J. Meierhans. It is used to control sucking pests, leaf miners, certain mites etc.

[B_2] Dichlorovos (DDVP/Nuvan) :

It is contact + Systemic poison and slow fumigant also. It brings about quick knock down effect. Its insecticidal properties were described. First in 1951 by CIBA. It does not leave any residue on plant and therefore it may be used on all crops until shortly before harvest. Soon after sprayed on leaves, it starts hydrolyzing into harmless dimethyl phosphoric acid and dichloroacetaldehyde which thereafter decomposes and evaporates. It is used to control household pests, lepidopterous larvae, sucking pests etc.

[B_3] Trichlorfon :

This product was prepared by W. Lorenz but was introduced by Bayer in 1952. It is a contact and stomach insecticide with some fumigant action. In an alkaline medium of above P^{H}–6, it is dehydrochlorinated and the principal product of this reaction is dichlorvos. In insects its toxic activity is attributed to metabolic conversion to dichlorvos. It is quick acting and effective against lepidopterous and dipterous pests and sucking insects. Registered formulation are 5% DP, 50% EC and 5% Gr.

[B_4] Phosdrin (Mevinphos) :

For a short period, it is a good insecticide to control sucking and chewing insects. But it is rapidly hydrolysed in alkaline medium.

[B_5] Monocrotophos (Nuvacron/Corophos) :

It is highly effective organophosphate insecticide which has systemic and contact action. It is *acaricide* also. It is effective against thrips, leafminers, chewing and sucking pests. It is harmless on the normal recommended dosage. It should not be mixed with the alkaline pesticides.

[B_6] Parathion (Thiophos) :

Its insecticidal properties were first described by Schrader in 1944. It is known for contact action whose effect is rapid. It may be used as nematicide. It is not suitable for alkaline medium.

[B_7] Methyl Parathion :

The toxicity of Methyl Parathion is comparatively very less to mammals but highly toxic to insects. Therefore its use is comparatively more. It is used to control a wide range of pest. Registered formulation is 2% DP and 50% EC.

[B_8] Malathion :

It was introduced in 1950. Its toxicity for mammals is very low e.g. acute oral LD_{50} for rat is 2800 mg/kg. It is corrosive to iron and on prolonged contact with it loses its insecticidal activity. It is incompatible with alkaline pesticides. It is a non-systemic and used to control a

wide variety of pests especially in fruits, vegetables and stored grain pests and external parasites of livestock. It is harmless for almost all corps except ornamental plants. It's technical product is 95% pure.

Although its low mammalian toxicity, there should be a gap of at least 4 days between the spraying the crop and its harvesting.

[B_9] Diazinon :

It was introduced in 1952 but its insecticidal properties were described in 1953 by R. Gasser. It is a contact & stomach poison with fumigant action and penetrating effect. It has nematicidal effect also. It is used to control aphids, thrips, mites and houseflies. It controls soil insects successfully. It should not be mixed with Copper fungicides. It is harmless for crops but it may harm to tomato and cucumbers at low temp.

[B_{10}] Dimethoate (Rogor) :

It was described in 1956. It is a systemic and contact insecticide and acaricide. It is used to control a wide variety of sucking pests & lice infesting poultry. It loses its insecticidal properties in alkaline medium. The crop should be irrigated before spraying it. It is formulated as 30% EC.

[B_{11}] Thimet (Phorate) :

It is a systemic insecticide and mainly used for soil treatment to protect the crops at the sowing time. It has contact and fumigant action and to some extent nematicidal and acaricidal action also. It does not persist for a longer period. It is also effective against sorghum shootfly and rice gallfly. It is formulated as 10% a.i. granules. It protects the crop for 20-25 days.

[B_{12}] Metasystox (Methyl demeton) :

It is comparatively more effective than systox (Demeton). It is a systemic insecticide and effective against sucking pests. Its formulation is 25% EC.

[B_{13}] Chlorfenvinphos :

It's insecticidal properties were described in 1962 by W.F. Chamberlain et. al. It is contact insecticide effective against pests resistant to organochlorines. It is used to control root flies, cutworms etc. as a soil insecticide. @ 2 – 4 kg a.i./ha and on foliage stem borers, leaf hoppers, leaf beetles etc. It's registered formulation in India is 10% granules (Gr.)

[B_{14}] Chlorpyrifos :

Keraga et. al described its insecticidal properties in 1965. It is effective against sucking and chewing pests and household pests particularly in mosquito larval control @ 0.5 kg a.i./ha. It is rapidly detoxified in the animal body. Registered formulations are 20% EC, 10% Gr & 1.5% DP.

[B_{15}] Phosalone / Zolone :

It is a non-systematic contact insecticide and acaricide effective against a wide spectrum of pest spp., particularly of cotton. It is safe to bees and natural enemies of pest spp. Formulation is 4% dust & 35% EC.

[B_{16}] Quinalphos :

Its insecticidal properties were discovered in 1969 by Schmidt & Hammann. It is an insecticide and acaricide with contact and stomach action. It is used to control sucking insects and lepidopterous larvae particularly of cotton and rice. Formulation is 25% EC, 5% granule & 1.5% dust.

[B_{17}] Triazophos :

It is a broad spectrum insecticide/acaricide with contact & stomach action and efective against lepidopterous larvae etc. on cotton, vegetables etc. Registered formulation are 20% EC & 40% EC.

[B_{18}] Propetamphos :

It is a contact & stomach insecticide with long residual activity. It is effective against household and public health pests especially cockroaches, flies, fleas, mosquitoes, clothes moth, ants and animals ectoparasites such as

lice, ticks & mites. Registered formulations are 20% EC & 1% spray.

[C] 'S'– Containing Insecticides :

(a) Metasystox
(b) Rogor (Dimethoate)
(c) Malathion
(d) Parathion (Thiophos)
(e) Methyl Parathion
(f) Dimeton (systox)
(g) Propetamphos
(h) Fenitrothion
(i) Diazinon
(j) Coumaphos
(k) Phorate
(l) Endosulfan
(m) Chlorpyrifos
(n) Phosalone
(o) Quinalphos
(p) Triazophos

[D] Carbamate Insecticides :

Carbamate compounds are derivatives of Carbamic acid and dithiocarbamic acid. Organophosphates are highly effective against a wide spectrum of insect-pests due to their capacity for inhibiting cholinesterase in insect nerve tissue. In the same way some Carbamates (e.g. aryl esters of N-methyl carbamic acid) show insecticidal properties becoming competitive inhibitors of cholinesterase. The insecticidal properties of carbamates are attributed to their structural resemblance to acetylcholine and thus have a high affinity for the particular enzyme cholinesterase.

[D_1] Carbaryl (Sevin) :

H.L. Haynes et. al first time pointed out its insecticidal properties and was introduced in 1956. It is a contact insecticide with slight systemic action. It is comparatively safer for human and mammals than chlorinated and Organophosphates. It is effective against a wide spectrum of insects pests of crops particularly cotton but ineffective against mites. It should not be mixed with alkaline compounds. It is formulated as 5% or 10% dust, 4% granules & 50% WP or 85% SP or 40% LV

Sevidol (granules) = 4% Carbaryl + 4% γ-HCH used to control rice pests

Sevimol 40LV = 40% Carbaryl + Molasses.

[D_2] Carbofuran (Furadan) :

It is an systemic insecticide and nematicide effective against sucking and soil inhabiting pests. It is used to control sorghum shootfly. It is unstable in alkaline medium, Its application stimulates growth in cotton, rice, tobacco, sorghum and corn. It is formulated as 50% SP and 3% granule.

[D_3] Carbosulfan :

It is effective against a broad spectrum of pest species on various crops. It is metabolized in plants to carbofuran and 3-hydroxycarbofuran.

[D_4] Aldicarb (Temik) :

It is a systemic insecticide, acaricide and nematicide and highly poisonous for mammal. Its insecticidal properties were described by M.H.J. Weiden et. al. and was introduced in 1965.

[D_5] Methomyl :

It is effective against sucking insects and mites and lepidopterous larvae especially cabbage looper and diamond back moth. It also controls nematodes.

[E] Synthetic Pyrethroids :

The First synthetic analogue of pyrethrum was Allethrin which was firstly developed by Green & La Forge in 1949. Since then so many synthetic pyrethroids have been developed.

[E_1] Allethrin :

It is known for quick knock down effect on flies and mosquitoes when applied with synergists like piperonyl bitoxide.

[E_2] Cypermethrin :

It was discovered by M. Eliott et. al in 1975. It is a stomach and contact insecticide effective against various lepidopterous larvae particularly boll worms & leaf eating caterpillars of cotton. Formulations are 10% EC & 25% EC.

[E_3] Etofenprox :

It is non-ester pyrethroid introduced in 1987. It is a contact stomach insecticide. It is effective against Rice leaf hoppers and brown plant hopper (BPH). It is also effective against cockroaches and houseflies. Its Formulation is 10% EC.

[F] Acaricides :

Such chemical controls or kills the acarina (mites) is called acaricide. Aramite is the ideal acaricide which controls mites. It is harmless for predators, human and animals. DINOCAP is an another acaricide and contact fungicide and was firstly introduced in 1946 by Rohm and Hass company. Trade name of DINOCAP is ***Karathane.*** The registered formulation of DINOCAP is 48% EC. Other acaricides are : Azobenzene, Dicofol, chlorobenzilate, Chlorafenson, Fenson, Tetradifon, chlorben, side, abamectin, Flufeboxuron.

General dose :

Systemic Pesticides @ 0.02 – 0.05% a.i. for spray.

Contact pesticides @ 0.05 – 0.07% or even 1.0% a.i. for spray.

Granular systemic insecticides @1-2 kg a.i./ha for soil application.

Fungicides @ upto 2 g/l depending upon chemical used, pest species and season of application.

4. Fumigants :

Fumigants are such pesticides which have the capacity to kill the particular pest by converting into gaseous state at the required temp. and pressure. It is also called gaseous poison. Such gas enters into the larvae, pupae and adults of insects through spiracles and the eggs through the chorion during respiration and thus brings about death. Fumigant may kill all types of insects because it has no significance of mouth parts and feeding habit of insects. Such fumigant which vapourizes readily at the room temp. is the most useful. The essential feature of soil fumigant is that the released vapour must be slowly.

Fumigation is required to kill or control a great variety of pests of stored products, household articles, soil inhabiting

insects & nematodes as well as for a quarantine measures at the time of export-import. The following prevalent fumigants are :

(i) HCN (Hydro-cyanic acid or Hydrogen Cyanide) : It is most extensively used fumigant and was firstly used to control cottony cushion scale *Icerya perchasi* in 1886 by D.W. Coquillett. HCN is obtained from treating the sodium with sulphuric acid.

(ii) Bromo-methane/Methyl bromide. It is 1.5 times heavier gas than air, therefore its penetration power is remarkable. In 1932, its insecticidal properties were described by Le Goupil. It is used to control soil insects, nematodes, soil weeds and fungi and rodents.

(iii) Chloropicrin (Trichloro-nitromethane): It is a tear gas. Its use is not registered in India.

(iv) Ethylene dibromide (EDB): Its insecticidal properties were described by Neifert et. al. in 1925. It is used for fumigating fresh fruits and vegetables to control fruitfly larvae because it does not affect plant materials. It is also used to control nematodes (except cyst nematodes *Heterodera* spp. and soil fungi).

(v) Phosphine (PH_3) / Hydrogen phosphide : It is widely used in fumigating grains, flour and cereals in godowns. PH_3 is liberated from Aluminium phosphide in presence of moisture:

$$AlP + 3H_2O \rightarrow \mathbf{PH_3}\uparrow + Al\,(OH)_3$$

But it is available in the market in the pellet forms. The combination of pellet is 55% Aluminum phosphide, 40% ammonium carbamate and 5% aluminium oxide. PH_3 is highly toxic to all stages of insects and rats. The pellet containing ammonium carbamate releases CO_2 and ammonia (NH_3) which prevent spontaneous ignition of phosphine gas. And the final product formed is aluminium hydroxide which is harmless. A pellet (Tablet) weighing about 3 kg liberates 1 kg PH_3 approximately.

Celphos is the such tablet.

Other fumigants are Nicotine, carbon disulphide (CS_2) Dichloropropene, vapam, Napthalene etc.

[5] Rodenticides :

Generally two types of poison are used to kill rats/rodents:

(a) Acute Poison : It includes

(i) Antu (ii) Barium Carbonate

(iii) Zinc Phosphide (iv) Thallium Sulphate

(v) Arsenic Compound

Pre-baiting is required for all the poisons.

(b) Chronic/Multidose Poison : Such poisons are anticoagulant which are derivatives of hydroxy-coumarin. Anticoagulant is the name of that compound which prevents the blood clotting. The prevalent examples are-warfarin (tomorin/ Coumachlor), Diphacinone, Coumafuryl, Coumatetralyl, Bromadiolone.

To control the mole rats (which live in the burrow), Aluminium phosphide ($PH_3\uparrow$) is used.

(6) The maximum use of pesticides in India is on cotton (more than 50% of the total pesticides used) 2nd on cereals and 3rd on Fruits & vegetables. The Insecticide accounts for 80% of the total pesticides.

(7) The enzymes present in the plant is responsible for the detoxification of pesticides in the plant body.

[8] Generations of Insecticides :

(i) First generation of Insecticides : The majority of the Insecticide used before the second World War were Inorganics and a few were Plant's origin. But the discovery of DDT in 1939 revolutionized the concept of chemical method of Insect control. Just after this discovery, γ-isomer of BHC was discovered. Schrader described the Organophosphates and thus the initial stage of the use of Chlorinated and Organophosphates is known as Ist generation of Insecticides.

(ii) 2nd generation of insecticides : After the Ist generation of insecticides those insecticides have been used

which have less toxicity and more selective effect on target organism. This generation is known for modern synthetic insecticides. India is now crossing the 2nd generation.

(iii) 3rd generation of Insecticides: The era of target specific and non-toxic insecticides e.g. the use of Juvenile hormone, repellents, sex attractants etc. is called 3rd generation. such insecticides are used in vogue in developed countries but also gaining momentum in our country.

(iv) Fourth generation of Insecticides : The use of anti-hormonal (precocene) insecticides is called fourth generation e.g. U.S.A.

[9] Insecticide Additives :

Only a small quantity of the poison or toxicant is required to control the pest. Such a small quantity is difficult to apply in an effective manner. Therefore the toxicant is required to be formulated. The volume of the toxicant is increased by adding inert materials to the pure and technical form of Poison. The inert material is called Additive and the process to get mixture by adding inert materials to the pure and technical form is known as Formulation. The common formulations are :

(i) Dust Additives :

Toxicant + Carriers/Extenders/Diluents/Vehicles.

Particle's size is the determing factor to choose the carrier.

Dust Carrier :

(a) Organic Compounds e.g. Flour of Walnut, Soybean, Shell, & Woodbark.

(b) Inorganic compounds e.g. Pulverized mineral (sulphur, diatomite (Silicon oxide) tripolite, lime, gypsum, talc, pyrophyllito or clay (attapulgite, benetonites, kaolins, volcanic ash).

(ii) Spray Addititives :

(a) Solvent : Kerosene Oil, diesel of petroleum, xylene etc. are used as solvents.

(b) Wetting agents : It is required to convert a water insoluble toxicant into a soluble or partly soluble one.

(c) Emulsifier : It is required to prevent a solvent dissolved toxicant from precipitating out. e.g. sodium oleate, amines, sodium lauryl sulphate etc.

Commercially many pesticides are sold in the market as an Emulsifiable concentrate (EC).

EC = toxicant + solvent + Emulsifier + Water

+ water means the recommended amount of water which is required to add at the time of use.

(d) Spreader/Deflocculator : Such additives are required to improve wetting through spreading property e.g. Calcium caseinate, Soybean flour, sulphated alcohols or sulphonated compounds etc.

(e) Sticker : It prevents the pesticide from washing off by rain or dew e.g. gelatin, resin, glue, starch, vegetable oil etc.

(f) Stabiliser : Such additives are required to retard rapid decomposition of unstable organic pesticides e.g. isopropyl cresols, hexamethylene tetramine & epichlorohydrin prevent the decomposition of pyrethrins, endrin and aldrin respectively.

(g) Softener : It reduces the phytotoxicity of pesticide e.g. sulphur, zinc sulphate, lime casein etc.

(h) Masker or Deodorant : It suppresses (masks) the unpleasant odours when used for household purposes e.g. cedar oil, pine oil, scents etc.

10. Types of Formulation :

[A] Solid Formulation :

(i) Dust : Such mixture which is obtained by mixing toxicant with the dust carrier, is called dust. Dust is the general term of the particle having the size less than 100 micron (μ).

Finished Product	=	toxicant	+	carrier
		0.1 – 25%		99.9 – 75%

The amount of toxicant ranges from 0.1% to 25% and the rests in the dust formulation are carriers.

Lesser the particle size, higher the toxicity. Particle size of the Dust formulation = 1 – 40μ

(ii) Granules :

Toxicant : 2 – 10%

Particle size : 0.25 – 2.5 mm diameter
but usually 250μ – 1250μ
i.e. 0.25 mm – 1.25 mm

Those having particle size 100μ - 300μ are called micrognanules and those above 300μ are known as granules.

Micrognanules : 100μ – 300μ
Granules : > 300μ

(iii) Insecticide – Fertilizer mixture is also prepared to control the soil insect.

[B] Liquid Formulation/Spray :

(i) Concentrate liquid or Undiluted liquid: The Highly concentrated liquid of technical grade of the toxicant is dissolved in non-volatile and non-phytotoxic solvents. To enable solution and drop formation a volatile solvent is also added but emulsifier is not added. The concentrate liquid formulations of Malathion & Fenitrothion are used in ultra-low-volume (ULV) quantities.

(ii) Solution Concentrate (SC)/Solution: Such pesticides are formulated in a single liquid phase either in water or in an oil.

In water : Monocrotophos, Organophosphates
In Oil : Flint type domestic spray.

(iii) Emulsifiable concentrate (EC) : Such formulation contains the toxicant, a solvent. For the toxicant and an emulsifying agent i.e. emulsifier

E.C. = toxicant + solvent + Emulsifier

It may be of two types

(a) Oil in water type (b) Water in oil types

Reasons to add emulsifier are :

(a) To dilute water insoluble chemical (with water).

(b) To spread and wet the treated surface by reducing the surface tension of the spray.

(c) To stablize the emulsion.

(d) A better contact is possible with insect cuticle.

(iv) Suspension : In such formulations, active materials are suspended as solid particles in water.

Such formulation is required when an active ingredient is

insoluble in either water or organic solvents. Such formulation is called suspension or **Flowable (F) or suspension concentrate**.

(v) Foam : Foam producing nozzle converts the pesticide spray into foam.

(vi) Mist : Very small droplets are called mist.

Droplet size : 50 – 150μ (micron)

$[1\mu = 10^{-6}\mu]$

Droplet size means the median diameter of the droplet.

(vii) Fog : Its droplet size is more lesser than mist:

Droplet size : 1 – 50μ

[Particle size of smoke : 0.001 – 0.1μ]

(viii) Aerosols : When minute droplets or particles are suspended in the air like mist or fog, are called aerosols i.e. aerial solution.

Droplet or particle size : 0.1 – 50μ

A more popular form of aerosol formulation is ***aerosol bomb*** which is used in household or camps to kill mosquitoes.

(ix) Water Dispersible Powder/Weltable Powder : (WDP/WP) : W.P. is the powder formulation which yields rather stable suspension when diluted with water. Water insoluble toxicant is mixed with carrier. Carrier is partly soluble in water and is capable of making a fine suspension in water and thus such mixture is called WDP. The active ingredient in W.P./WDP ranges 15-95% but commonly a.i. is 25-50%.

The concentration of toxicant is comparatively more than that of Dust.

(x) Water Soluble Powder (WSP/SP) : WSP is a powder formulation readily soluble in water. It usually contains a high conc. of active ingredient and therefore easy to store and transport. e.g. Carbaryl 85 SP and Acephate 75 SP.

[C] Gaseous Formulation :

It is also called fumigants.

Particle size of smoke, 0.001 – 0.1μ.

[II] Classification of Spray Volumes :

(a) High Volume Spray (HVS) : Here spray liquid is used more than 400 *l*/ha.

$\Rightarrow$ 400 *l*/ha of spray liquid used

(b) Low volume Spray (LVS) : 5 – 400*l*/ha of spray liquid.

For aerial dose : 15 – 75 *l*/ha

Ground dose : 100 – 200 *l*/ha

(C) Ultra-low volume spray (ULV) or Low volume concentration spray (LVC) :

ULV/LVC : < 5 *l*/ha of spray liquid used.

Here quantity of formulation is less than 5 *l*/ha and more concentrated formulation is used without diluting with water. To compensate the low (Small) volume, it is required to break down the concentrate into extremely fine particles. In India ULV is sprayed by the aircraft e.g. Malathion conc. (95% a.i.). In our country, due to lack of proper equipments, the ULV spray is generally used in aerial spray. Aerial spraying is done by both by *fixed-wing aircrafts* and *helicopters*. For ground spraying, Aspee's modified mist blower and Knapsack are used.

12. Calculations Regarding Formulation :

Question 1. The quantity of endosulfan 35% EC required for treating an area which needs 1000 litres of spray fluid at 0.05% (a.i.) strength is

(a) $35 \times 0.05/1000$ litres (b) $2.5 \times 1000/1000$ litres
(c) $1000 \times 0.05/35$ litres (d) $35 \times 1000/0.05$ litres

Solution :

By the formula :

$$\text{Amount of insecticide required (kg)} = \frac{\text{Total spray required } (l) \times \text{Percent Strength required}}{\text{Given percent strength}}$$

Therefore, $\dfrac{1000 \times 0.05}{35}$ litres Ans – c

Q.2. Spraying of one hectare of cotton crop is done using 500 litres of spray fluid prepared from 2 kg of Carbaryl 50% water dispersible powder. The concentration of active ingredient of Carbaryl in the spray fluid is

(a) 1% (b) 0.2 %
(c) 0.1% (d) 0.5%

Solvn.

Here,
Total spray liquid = 500 *l*
% strength required = ?
Amount of insecticide required = 2 kg
Given percent strength = 50%

By the Formula :

$$\text{Amount of insecticide required (kg)} = \frac{\text{Total spray required } (l) \times \text{Percent Strength required}}{\text{Given percent strength}}$$

$$\Rightarrow \quad 2 = \frac{500 \times \%\ \text{Strength required}}{50}$$

$$\%\ \text{Strength required} = \frac{50 \times 2}{500} = 0.2\%$$

Ans. – b

Q.3. The quantity of liquid insecticide with 25% active ingredient required for preparing 500 litres of the spray fluid of 0.25% strength is

(a) 1.25 litre (b) 2.5 litre
(c) 5.0 litre (d) 10 litre

Solution :

Here,

Amount of insecticide = ?
Required % strength = 0.25%
Required total spray = 500 *l*
Given % strength = 25% a.i.

By the formula:

$$\text{Amount of insecticide required (kg)} = \frac{500 \times 0.25}{25} = 5\ l$$

Ans – c

Q.4. What is the amount of Bavistin 50W required to be added to 1000 litres of water to make a spray mixture of 0.05% a.i. concentration ?

(a) 0.5 kg (b) 1.0 kg

(c) 1.5 kg (d) 2.0 kg

Soln. Amount $= \frac{1000 \times 0.05}{50}$ kg $= 1.0$ kg

Ans. – b

Q.5. What is the concentration of active ingredient in the spray liquid when one gram of pesticide formulation having 50% active ingredient is mixed with one litre of water ?

(a)0.5 ppm (b) 5.0 ppm

(c) 50 ppm (d) 500 ppm

Soln. Here,

Required total spray liquid = 1 l (one litre)

Required strength percent = ? (to find out)

Given strength percent = 50% a.i.

Total amount of Pesticide = $1\text{g} = \frac{1}{1000}$ kg .

From the formula :

$$\text{Total amount of pesticide (kg)} = \frac{\text{Required total spray liquid } (l) \times \text{Required Strength percent}}{\text{Given strength percent}}$$

$$\Rightarrow \frac{1}{1000} = \frac{1 \times \text{required \% strength}}{50}$$

$$\Rightarrow \text{Required \% strength} = \frac{50}{1000} = 0.05\%$$

ppm means parts per million (10^6)
Here required % Strength = 0.05%

$\Rightarrow$ 0.05% means in 100 there is 0.05

$$\because \quad \text{in } 10^6 — \frac{0.05}{100} \times 10^6$$

$$= 0.05 \times 10^4$$
$$= 500$$

It means 500 parts per million

$\Rightarrow$ 500 ppm

Ans.– d

Table : Classification of pesticides

Main groups	**Subgroups**	**Examples**
	Insecticides	
Inorganic		Aluminium phosphide, calcium arsenate
Botanical (plant extracts)		Nicotine, pyrethrins, rotenone, azadirachtin
Organic	Hydrocarbon oils	Citrus spray oils, dormant spray (winter washes), mosquito larvicides
	Organochlorines	Aldrin
	Organophosphorus	
	Contact	Azinphos-methyl, dichlorovos, parathion-methyl, Feritrothion, Malathion, Parathion
	Systemic	Demoton-methyl, Dimethoate, Monocrotophos, Phosphomidon
	Carbamates	
	Contact	Carbaryl, Methomyl, Propaxur
	Systemic	Aldicarb, Carbofuran
	Synthetic pyrethroids	Cypermethon Penvalerate Deltamethrin
Microbial	Bacterial	Bacillus thuringiensis
	Viral	Polyhedral viruses
	Other insect control agents	
Chemo-sterilants		Diurea, tepa, metpa
Pheromones (sex atractants)		Gyplure, Gossyplure
Repellents		Deet, dimethyl phthalate, ethyl, hexenediol
Insect growth regulators	Juvenoids (juvenile hormone) Moulting inhibitor	Farnesol, methopreril, Diflubenzuron, ecdysone
	Acaricides	
Non-fungicidal	Organochlorines	Chlorobenzilate, Dicofol Tetradifon
	Organo-tin	Cyhexatin, Fenbutatin
Fungicidal	Dintro compounds	Binapacryl, Dinocap
	Others	Chinomethionate
	Protectant fungicides	
Inorganic Oxychloride, sulphur		Bordeaux Mixture copper
Organic	Dithiocarbamates	Mancozeb, Methiram, Propineb, Thiram, Zineb
	Phthalimides	Captafol, Captan, Folpet
	Dinitro compounds	Binapacryl
	Organomercurials	Phenyl mercury acetate and chloride
	Organo-tin compounds	Fentin (acetate hydroxide)

	Others	Chinomethionate, chlorothalonil, Dischlorofluonid, Dichlone, Dyrene, Dicloran, Dodine, Glyodin
Eradicant fungicides (Chemotherapeutants)		
	Antibiotics	Blasticidin, Cyclohexamide, Kasugamycin, Streptomycin
	Morpholines	Dodemorph, Tridemorph
	Formylamino compounds	Chloranifomethane, Trifornie
	Others	Ethirimol, Carboxin dioxide, Benomyl, Tiabendazole, Thiophanate-methyl
Soil fumigants and nematicides		
Soil sterilant	Halogenated-hydrocarbons	Chloropicrin, Methyl bromide
	Methyl-isothiocyanate	Dazomet,Metham
	Others	Carbon disulphide, Formaldehyde
Fumigant nematicide	Halogenated-hydrocarbons	DD, Dichloropropene, Ethylene dibromide
Non-fumigant nematicide	Organophosphorous compounds	Fensulfothion, Fenmiphos
	Carbamates	Aldicarb, Carbofuran
Herbicides		
Inorganic		Sodium arsenite, Sodium chlorate
Organic	Phenolics	Bromofenoxim, Dinoseb acetate DNOC, Notrofen, PCP
	Phenoxyacids (hormone weed killers)	CMPP, MCPA, 2, 4-D, 2, 4, 5-T
	Carbamates	Asulam, Barban, Bendiocarb, carbetamide, chlorpropham, Phenmedipham, Propham triallate
	Substituted ureas	Diuron, Fluometuron, Linuron, Metrobromuron, Monolinuron
	Halogenated aliphatics	Dalapon, TCA
	Triazines	Ametryn, Atrazine, Methoprotyne, Simazine, Terbuturyn
	Diazines	Bromacil, Lenacil, Pyrazon
	Bipyridyls	Diquat, Paraquat
	Pyrazolium	Difenzoquat
	Benzoic acids	Chlorfenprop methyl, Dicamba, 2,3,6-TBA

	Arsenicals	Cacodylic acid, DSMA, MSMA
	Dinitroanilines	Nitralin, Profluralin, Trifluralin
	Benzonitriles	Bromoxynil, Chlorthiamid, dichlobenil, Loxynil
	Amides and anilides	Benzoylprop-ethyl, Diphenamid, Propachlor, Propanil
	Others	Aminotriazole, Flurecol, Glyphostate, Picloram
	Desiccants, defoliants	
	Quaternary ammonium compounds (bipyridyls)	Diqual, Paraquat
	Phenolics	Cacodylic acid, Dinoseb, DNOC PCP
	Plant growth regulators	
Growth promoters (auxins and auxin type)		Gibberellic acid
Growth inhibitors (stem shorterners)	Quaternary ammonium compounds	Chlormequat
Sprout inhibitors and dosuckering agents	Carbamates	Chlorpropham propham
Fruit setting, ripening, flowering agents and latex stimulants	Ethylene generators Others	Ethephor Dimas, Glyphosine, Naphthalaneacetic acid
Fruit-drop induction (abscission agents)	Cycloheximide	
	Rodenticides	
Fumigants		Aluminium phosphide, cyanide, Chloropicrin, Methylbromide
Anticoagulants	Hydroxy coumarins	Counmate tralyl Difenacoum
	Indandiones	Chlorophacinone, phenyl methyl pyrozolone,Pindone
Others	Arsenicals	Arsenious oxide Sod. arsenite
	Thioureas	Antu,Promurit
	Botanicals	Red squill, strychnine
	Others	Norbomide Sodium Fluoro acetate, Vitamin D (calciferol), Zinc phosphide
	Molluscicides	
Aquatic	Botanicals	Endod
	Chemicals	Copper sulphate Sodium Niclosamide Pentachlorophenate trifenmorph
Terrestrial	Carbamates	Aminocarb, Methiocarb Mexacarbate
	Others	Metaldehyde

Table : Pesticides registered in India under Insecticides Atc, 1968

2, 4-Dichlorophenox Oxy acetic acid	Barium carbonate	Carbosulfan
	Benfuracarb	Carboxin
Acephate	Benomyl	Cartap hydrochloride
Acetamiprid	Benthiocarb (Thiobencarb)	Chlorimuron ethyl
Alachlor	Beta cyfluthrin	Chlormequat Chloride (CCC)
Allathrin	Bifenthrin	Chlorofenvinphos
Alfacypermethrin	Bitertanol	Chlorothalonil
Alfanapthyl acetic acid	Bromadiolone	Chlorpyriphos
Aluminium phosphide	Butachlor	Cinmethylene
Anilophos	Captafol	Clomazone
Atrazine	Captan	Copper hydroxide
Aureo fungin	Carbaryl	Copper oxychloride
Azadirachtin	Carbendazim	Copper sulphate
Bacillus thuringiensis (B.t.)	Carbofuran	Coumachlor
Coumatetralyl	Fluchloralin	Paraquat dichloride
Cuprous oxide	Flufenoxyuron	Penconazole
Cyfluthrin	Fluvalinate	Pendimethalin
Cyhalotop-butyl	Formothion	Pormothrin
Cymoxanil	Fosetyl-Al	Phenthoate
Cypermethrin	Gibberellic acid	Phorate
Cyphenothrin	Glufosinate ammonium	Phosalone
Dalapon	Glyphosalo	Phosphamidon
Dazomet	Hexaconazole	Piroxofop propanyl
Decamethrin (Deltamethrin)	Hydrogen cyanamid	(clodinafop-propmyl)
Diafethioron	Imazethapyr	Prallethrin
Diazinon	Imidacloprid	Protilachlor
Dichloro diphenyl trichloroethane (DDT)	Imiprothrin	Primiphos-methyl
	Indoxacarb	Profenophos
Dichloropropene and dichloropropano mixture (DD mixture)	Iprodione	Propanil
	Isoprothiolane	Propargite
	Isoproturon	Propetamphos
Diclofop-methyl	Kasugamycin	Propiconazole
Diclorvos (DDVP)	Kitazin (Iprobenfos)	Propineb
Dicofol	Lambdacyhalothrin	Propoxur
Difenocenazole	Lime sulphur	Pyrethrins (pyrethrum)
Diflubenzuron	Lindane	Quinolphos
Dimethoate	Linuron	S-Bioallethrin
Dimethomorph	Malathion	Simazine
Dinocap	Mancozeb	Simate
Dithianon	Metalaxyl	Sodium cyanide
Diuron	Metldehyde	Sterptomycin
Dodine	Metasulfuron methyl	Sulfosulfuron
D-trans allethrin	Methabenzthiazuron	Sulphur
Edifenphos	Methomyl	Tebuconazole
Endosulfan	Methoxy ethyl mercury chloride (MEMC)	Temephos
Eretilachlor		Thiodicarb
Ethephon	Methyl bromide	Thiomethoxain

Ethoxysulfuron	Methyl parathion	Thiram
Ethylene dibromide and carbon tetrachloride mixture (EDCT mixture)	Metolachlor	Transfluthrin
	Metoxuron	Triadimefon
	Metribuzin	Triallate
Fenarimol	Monocrotophos	Triazophos
Fenazaquin	Myclobutanil	Trichlorofon
Fenitrothion	Nickel Chloride	Tricyclazole
Fenobucarb (BPMC)	Oxadiargyl	Tridemorph
Fenoxaprop-p-Ethyl	Oxadiazon	Trifluralin
Fenpropathrin	Oxycarboxin	Validamycin
Fenthion	Oxydemeton-methyl	Warfarin
Fenvalerate	Oxyfluorfen	Zinc phosphide
Ferbam	Paclobutrazole	Zineb
Fipronil	Paradichlorobenzene (PDCB)	Ziram

Table : Pesticides banned for manufacture, import use

1.	Aldicarb
2.	Aldrin
3.	BHC
4.	Calcium cyanide
5.	Captofol powder (80%)
6.	Carbofuran (50% wp)
7.	Chlordane
8.	Chlorobenzilate
9.	Chlorobromopropane
10.	Copper acetoarsenite
11.	Dieldrin
12.	Endrin
13.	Maleic hydrazide
14.	Menazone
15.	Methomyl (12.5%)
16.	Methomyl (24%)
17.	Nicotin sulphate
18.	Nitrofen
19.	Paraquat dimethyl sulphate
20.	Pentachloro nitrobenzene
21.	Pentachlorophenol
22.	Phenyl mercuric acetate
23.	Phosphamidon (85% SL)
24.	Sodium methane arsonate

(Courtesy : Handbook of Agriculture)

*

13 Plant Protection Equipments

Diluents are of three types viz. solid, liquid and gas. Accordingly respective application methods of pesticides are called dusting, spraying and fumigation and the equipments used in such application is named duster for dusting, sprayer for spraying and fumigator for fumigation.

Dusters

Introduction :

(i) It consists essentially of a ***Fan*** or ***Blower*** or ***Bellow Venturi*** and a type of container named ***Hopper***.

(ii) Bellow/Fan/Venturi is required to produce desired air current.

(iii) To produce air blasts is the basic principle of duster.

(iv) Duster is much lighter than sprayer.

(v) It is said that the efficiency of dusting is ten times more than that of spraying but the average job of spraying is equivalent to very good dusting.

(vi) The function of *nozzle* which is attached at the end of delivery tube is :

(a) To atomise (to break) the formulation into proper sized particles (or droplets) i.e. atomization of the particles.

(b) To provide proper shape to the outgoing formulation

(vii) How does duster work? – Dust particles are kept agitated and in motion in the hopper and then are fed into the air current to discharge the particles into fine dusts. And thus the fine dusts are dispersed both horizontally and laterally over a large area in cloud-form.

[A] Hand-operated duster or Hand Duster :

Such hand dusters are package duster, plunger duster, Bellow duster, Rotary hand duster, Traction duster.

(1) Package/container duster : It is of very primitive

type duster. It consists of a container and which, when is squeezed with fingers, dust is discharged with the small air stream. On squeezing the package or container, dusting is done. It is used at small scale in the kitchen garden and house. e.g. BHC dusting through muslin or fine cloth to kill bed bugs.

(2) Plunger (Piston) duster/Hand Pumps : It is operated by a plunger pump and dust is discharged through the outlet by the compression stroke of plunger pump. It is small and easy to operate. It is very cheap also. The double action plunger pump enables a continuous dusting operation. Upward movement of handle enables the dust to enter into the pump from the container and pushing of the handle i.e. downward movement enables the dust to discharge through nozzle. It is used at small scale in the kitchen gardens and houses. Since it is also used in fumigating the rodent burrows with calcium cyanide (Cyanogas) or sodium cyanide (Cyanomag), therefore it is known as ***Cyanogas pump*** or ***Foot pump duster***.

(3) Bellow Duster : It is operated through the expansion and contraction of a pair of bellows during which process the dust is sucked in and then thrown out into the delivery system. Dust is discharged by the air current produced by the movement of bellows. It is used in kitchen garden and domestic pest control.

(4) Rotary hand (Crank) duster :

(i) Air current is produced by ***Fan*** (blower).

(ii) Fan is driven by rotary motion of a handle through a reduction gear.

(iii) Here delivery of dust is direct from the fan.

(iv) Spoon type or fain tailed nozzles are effective.

(v) Feeding mechanism of dust is carried by a rotating brush inside i.e. ***Feeding brush***.

(vi) Discharge rate : 0.5 – 150g/minute at 35 rpm. (rpm = revolutions per minute)

(vii) Such duster is of two types viz. shoulder type and belly type. The use of Belly type is more comfortable.

(viii) It is quite popular for use in different crops and in different situations for treating small acreage and row crops like potatoes, tobacco, cotton etc.

(ix) It's hopper contains 5 kg material.

(5) Traction duster : Such duster is mounted on wheels and the blower fan is connected to the wheel. The traction (to push up) of duster runs the fan. It's use is for large scale dusting.

[B] Power (operated) dusters :

(i) Here power operated motors are used to run both the agitator inside the hopper and the blower (fan). Blower produces the air-blast.

(ii) Normally 1-3 hp (horse power) aircooled engines are used.

(iii) Hopper capacity is usually 10-20 kg.

(iv) Discharge rate : 1-9 kg/minute And an outlet coverage area in one hour is 12ha.

(v) The dust flow can be regulated from 0-1.5 kg per minute by adjustment of multi-hole discs.

(vi) Such dusters are large sized duster with hopper capacity of 500 – 1000 kg and is operated by more powerful engines (upto 25 hp.)

Sprayer

Introduction :

(i) Sprayers are the most commonly used in the pesticide application.

(ii) Three types of formulations are used in

(a) aquous solution in case of soluble toxicant

(b) suspension of particles in case of insoluble material.

(c) Emulsion in case of insoluble material.

(iii) Both Wettable powder (WP) and water dispersible powder (WDP) are suitable for high volume spraying and are not suitable for low volume spraying.

(iv) In sprayer, container is called 'Tank' but in duster it is called 'Hopper'.

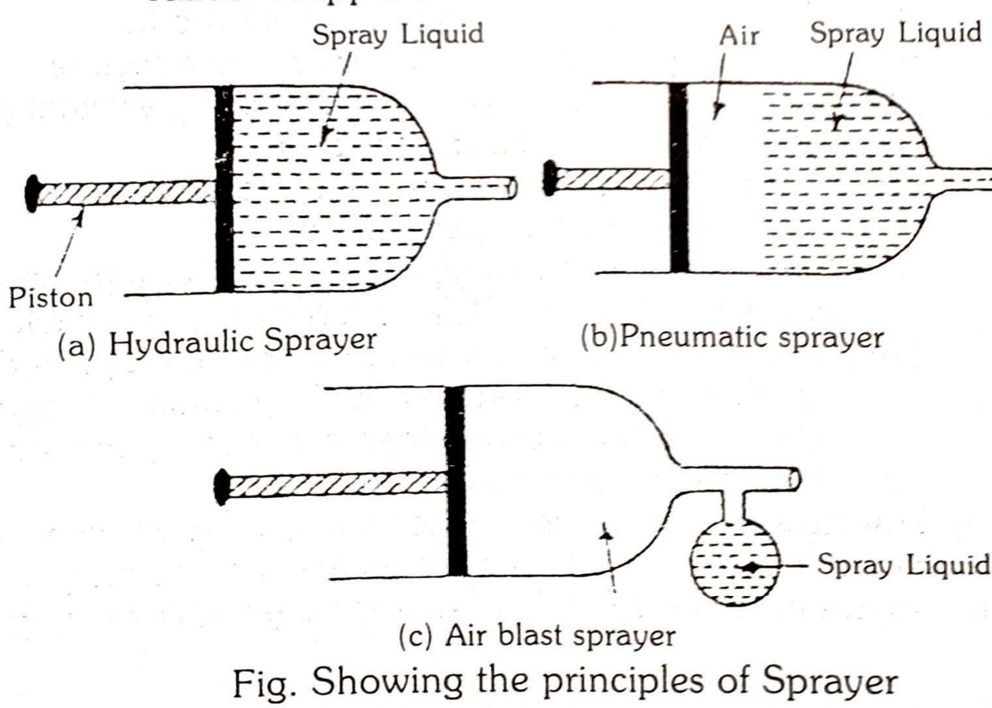

Fig. Showing the principles of Sprayer

(v) Sprayer : How to function? There are three main principles :

(a) To discharge the spray liquid it is directly pressed through a plunger or piston, such sprayers are called ***Hydraulic Sprayers***.

(b) To discharge the spray liquid, a layer of air is compressed through a plunger which in turn presses the spray liquid; such sprayers are called ***compression*** or ***Compressed Air*** or ***Pneumatic Sprayers***.

(c) To discharge the spray liquid, an air blast is produced through a plunger or a blower (fan) which atomises the spray liquid and carries it along to the target. Such sprayers are called ***air blast sprayers*** or ***blowers***.

(vi) Following essential parts are present in sprayers :

(a) Tank (b) Pump

(c) Nozzle (d) Agitator

(e) Pressure chamber (f) Pressure guage

(g) Hose (h) Spray lance.

(vii) Pump : It is used for atomization of the liquid through air. There are two basis for the pump selection:

(a) nature of the spray liquid.

(b) Pressure of discharge of the liquid through nozzle.

Types of Pump :

(a) Air/Pneumatic pump : It is mostly used in hand compression or pneumatic sprayers. It is used to force air into the airtight tank upto a certain pressure. It is really a force pump.

(b) Plunger or Piston Pump: It is used in power operated sprayer and generates high pressure upto 70 kg/cm^2. It is suitable for high volume spraying.

(c) Rotary Pump : It is of two types viz gear type and Roller vane type. Gear type rotary pump is used for low volume spraying and generates a pressure upto 4.2 kg/cm^2 whereas Roller vane type generates a pressure upto 8.4 kg/cm^2. Majority of the medium output sprayers are fitted with roller vane type rotary pump.

(d) Diaphragm Pump : It works on the same principle as the plunger pump works.

(e) Centrifugal or Impeller Type Pump: It generates pressure upto 7 kg/cm^2 and is not suitable for high pressure sprayers.

(f) Positive displacement pump.

(viii) Nozzles : Such device is used to break up the liquid coming out of the spray tank into fine droplets.

Function of nozzle :

(i) *atomization* of the spray liquid into proper sized droplets.

(ii) To impart desired *shape and angle* to the outgoing spray.

(iii) To regulate the *discharge* of the spray liquid per unit time at a known pressure.

Types of nozzle :

(a) Gaseous energy nozzle : Such nozzle consists of an orifice across which air is blown up at high speed to break up the liquid into fine (small) droplets. The drop size is dependent on the air velocity.

(b) Centrifugal energy nozzle : Fine mist forms of droplets are obtained from such nozzle which is used in ***ultra low volume*** *spraying* and ***aircraft*** *spraying*.

(c) Kinetic energy nozzle : Such nozzle consists of an oscillating tube having holes. The spray liquid is come out by gravity. It is suitable for ***herbicide*** application.

(d) Thermal Energy nozzle : Such type of nozzle is used for getting ***fogs***.

(e) Hydraulic nozzle : It is of two types :

(f) (i) Fan/Flat cone type : It has V-shaped orifice.

(ii) Cone/Swirl type : It has central aperture and swirling motion is given to the spray liquid in the chamber before emitting of spray. Higher the pressure, smaller the droplet's size. For getting better atomization and more efficiency, Cone nozzle is used but it is costly. It is used to spray on bushes and crop plants.

(ix) Effective droplet size :

(i) For Sprays : 100 – 400μ VMD

where μ = micron = 10^{-6}m

VMD : Volume Median Diameter

(a) For spraying Lawns : 400 – 500 μ

(b) For space spraying : 30 – 80 μ

(c) Droplet size of Mist (Kuhasa) : 50 – 150 μ

(d) Droplet size of Fog (Kuhara) : 1 – 50 μ

(e) Size of smoke particles : 0.001 – 0.1 μ

(f) Size of Dust particles 1 – 40 μ

(g) Size of granules : 0.25 – 2.4 mm (Millimeter)

(x) Classification of Spray Volumes :

(1) High Volume Spray : More than 400 litre/ha of spray liquid used i.e. > 400 *l*/ha of spray liquid.

(2) Low volume Spray : 5 – 400 *l*/ha

Normal aerial doze : 15 - 75 *l*/ha

Normal ground doze : 100 – 200 *l*/ha

(3) Ultra-low volume (ULV) or Low Volume concentration (LVC) Spray : Less than 5 litre/ha i.e. < 5 *l*/ha

(xi) In case of the spraying, the size of droplets less than 30 μ is more effective but the lightness of the droplets causes the drifting problem and the spray may not reach the target.

Hand Operated Sprayers :

[A] Hydraulic (Energy) Sprayers :

Here the size of droplets are mostly 300 – 400 μ. Such sprayes are high volume – High pressure sprayers and are suitable for complete coverage of both ground and field crops. Under this heading, followings are the sprayers :

(A_1) **Syringes :** It is the simplest hydraulic sprayer and very tiresome to operate. The rate of spraying is difficult to control. Therefore it is used only for small areas and Kitchen gardens and laboratories.

(A_2) **Bucket pump sprayer :** Suction hose is placed in the bucket. Spraying is done in both suction and delivery stroke, therefore spraying is continuous.

Although the rate of application is difficult to control. Its application requires only one person (operator) It is suitable for spraying shrubs, low crops (Vegetables) and nurseries.

(A_3) **Stirrup pump Sprayer :** It's application requires two operators i.e. one for pumping and agitating the suspension (if necessary) and another for spraying (application). It gives satisfactory performance and generates a pressure upto 4 kg/cm^2

To cover bigger areas for spraying, a bigger sized double action pump is fitted permanently in a large container and is mounted on wheels: which is commonly called wheel barrow type of Sprayers.

(A_4) **Knapsack/Backpack Sprayer:** The name of sprayer itself shows that it is used by carriying on ***Back*** of the operator. Spraying is done by right hand of the operator. It has double action lever. Here only one operator is required. Normally coarse nozzle is used to spray any type of material. Presently low volume nozzle is used to achieve low volume spraying. It is simple and durable, therefore it is useful for diverse use i.e. spraying the bush of ***tea*** and ***Coffee***. It is suitable for ***hilly*** and ***muddy*** tarains where the use of large or power sprayers is not possible.

(A_5) **Rocking Sprayer :** The word 'Rocking' means forward and backward movement of handle. It gives the pressure of 14-18 kg/cm^2. It requires two operators one for pumping system and another for spraying. It is used for spraying ***tall plants*** like ***arecanut, coconut*** and sugarcane etc. It gives uniform spraying at sufficient pressure.

(A_6) **Foot/Pedal Pump Sprayer :** It is based on the same principle of Rocker but here foot (Pedal) is used for rocking instead of hand. It means it may be used by only one operator. It may be used to spray ***tall trees*** with the help of extension rod. The plant up to of 6m height is easily sprayed. Therefore it is suitable for spraying

the trees in orchards and also for crops on medium sized farms. It generates a pressure of 14 kg/cm^2.

[B] Compression/Pneumatic/Air Sprayers :

(i) Air is compressed into the container by the compression air pump.

(ii) Tank is usually filled to 3/4th of its capacity and 1/4th (one-fourth) volume is left for the compressed air.

(iii) Such sprayers are not provided with agitators. Hence those spray materials which require continuous agitation for keeping them in suspension, normally can't be effectively sprayed.

(iv) Such sprayers can't be used for diverse purposes like hydraulic types.

(v) Flame Thrower is certainly a Pneumatic Sprayer.

(vi) It is of two types depending on the size viz compression hand sprayers and Pneumatic Knapsack sprayer.

(B_1) **Pneumatic/Compression Hand Sprayer :** The capacity of the tank of this sprayer is 0.5 to 3.5 litre and tank itself acts as pressure chamber. There is a provision of fine nozzles in these sprayers and due to this provision, solutions and emulsions can be effectively applied. Such sprayer is suitable for household and Kitchen gardens.

(B_2) **Pneumatic/Compression Knapsack sprayer :** It works on the same principle as of Hand Sprayer. It's tank is cylindrical and capacity is 10 to 20 litres. It is used by fixing on back of the operator. Pressure is developed 4-5 kg/cm^2. It is good for large areas.

[C] Gaseous Energy/Air Blast Sprayer :

The example of such sprayer is ***Hand Atomiser*** or ***Flint Pump*** which is the simplest air blast sprayer. The chamber capacity is 0.5 to 1 litre. It is suitable for experimental work on individual plants. The long time spray by this sprayer is tedious.

The working principle of such sprayer :

When plunger is pushed forward (downstroke) a gust (or blast) of air is come out from the nozzle which creates a momentary vacuum in the tube. Due to vacuum, spray liquid of the container rises out into the tube. When the plunger is drawn

backward (upstroke) fresh air enters into the barrel through its nozzle and the spray liquid (i.e. pesticide + air) is only to be expelled out by the next down stroke.

Power Sprayers

Such sprayers are used for large areas and on the basis of mechanism of action, these are of four types :

(A) Hydraulic energy sprayer
(B) Air Pump/Compressor or Pneumatic energy sprayer
(C) Gaseous Energy Sprayer or Blow applicator
(D) Centrifugal Energy Sprayer.

(A) Hydraulic Energy Sprayer : It is a High Volume – High pressure sprayer . Tank capacity is 160-200 litres and developed pressure is up to 40-50 kg/cm^2. High volume spraying is also called Full coverage spraying. It needs more water and obviously more labour is required. It is suitable for partially soluble or low dispersible chemicals (like Bordeaux Mixture) or highly soluble products (i.e. nicotine sulphate). Here phytotoxicity injury is minimized due to high degree of dilution. Clogging of nozzle is also avoided due to large aperture. Such sprayer requires 500-1000 litres of spray liquid for one hectare of field crop. Therefore it is ***not*** suitable for ***arid areas***.

Low Volume Spraying needs 8-25 times lesser amount of water and chemicals as compared to High Volume spraying. Therefore Low volume spraying is also called *concentrate spraying*. A water miscible liquid pesticide like malathion is more suitable for low volume spraying since it can be atomized without the danger of sedimentation. It needs 10-125 litres of spray liquid per hectare. i.e. 10-125 *l*/ha.

Semi-low volume/semi-concentrate spraying requires 0.5 – 6.25 litres of spray liquid/ha.

Recently ultra-low volume spraying i.e. ULVs is more prevalent where less than 6 litres of spray liquid is needed for one hectare i.e. < 6 *l*/ha. Low volume, low pressure with the use of a.i. in more concentrated form is the main principle of ULVs. Efficiency of low volume spraying depends on the droplet size and its spreading power. Therefore here more emphasis is given on to control droplet size to cover large area per unit time even with reduced consumption of pesticide.

Hydraulic energy sprayers are of two types viz.

(A_1) Small portable sprayer

(A_2) Large Sprayer

(A_1) **Small Portable Hydraulic Sprayer** : Generally it has two delivery hoze and it is operated by 1-3 hp aircoole dengine. It is suitable for spraying ground crops and orchards in plantation for smaller areas. It is available in the market in two forms-stretcher type and wheel-barrow type.

Stretcher type is light i.e. 20 kg in weight whereas wheel-barrow type is heavy that's why it requires one or more wheels.

(A_2) Large Hydraulic Sprayer : It's tank capacity is 200-2000 litres or more. The developed pressure is upto 28 kg./cm^2. Such sprayer is mounted on jeep or another vehicle. It is suitable for such field crops which has long rows and regular spacing with larger area. It is also used for orchards and plantations. It is unsuitable for tall field crops like jute, sugarcane at latter stage and wet rice field.

[B] Pneumatic/compression/Air Energy Sprayer:

There is no use of pump but a layer of compressed air is produced by Engine power over the spray liquid in the tank and the developed pressure is upto 14 kg/cm^2. Since there is no pumping action, such sprayer may be used for the spraying of corrosive materials provided the inner surface of the tank has an anti-corrosive lining. It is of two types :

(B_1) Portable and small mounted sprayer : The tank capacity is upto 50 litres. Single cylinder compressor is used to produce compressed air which is operated by V-belt air-cooled engine. There is no system of agitation hence is not suitable for spraying of materials which starts to sediment quickly.

(B2) Large mounted sprayer : Here the tank capacity is upto 2000 litres. Here there is a arrangement for agitation, therefore it is suitable for spraying of all types of formulations. It is expensive and difficult to use on small undulating lands. It's use is limited to level lands only.

[C] Gaseous Energy Sprayer :

It is a low volume – low pressure sprayer. When a strong current of air is thrown on the spray liquid coming out of the

sprayer, the air current atomises the spray liquid in the fine droplets. To throw air current at high velocity, *a fan/Blower* of 1.2 – 3 hp aircooled engine is required. Such sprayer is suitable for spraying concentrates but difficult to regulate the uniformity of spray deposits at different distances. It is known as ***Blow applicator***.

Some machines are so designed that both dusting and spraying may be done.

The droplet's size produced by such sprayer is 100-400 μ VMD (Volume Median Diameter)

Motorised knapsack sprayer is a blow applicator. Presently it is most common because of only one person is capable to treat more than 2 ha areas conveniently. The hopper attached with it is made up of polythin of high density whose tank capacity is 7-12 litres. One more tank is attached which is fuel tank and its capacity is 0.75 – 2.25 litres. It is operated by 1.2 – 3 hp aircooled engine. Its weight when empty is 7-15 kg. Therefore it is easily kept on back of the operator. The spray liquid is sprayed by strong air current having velocity of 175-320 km/h at which the discharge rate of air current is 2.7 – 9.1 cubic metre (m^3). The discharge of spray liquid is 0.5 – 5 *l*/minute and the fuel consumption is 0.6 – 1.86 *l*/hour.

The heavy Knapsack is not taken on the back of the operator. In such condition, it is of two types viz-stretcher type and wheel barrow type. Such sprayer is used for greater areas and for spraying on orchards and bushes. Motorised Knaksack sprayer is used for both dusting and ultra-low volume spraying.

[D] Centrifugal Energy Sprayer :

Such sprayers are designed to produce fine drops (50 – 150 μ VMD) in the form of mist hence called ***Mist blowers/ Mist Sprayers.*** The centrifugal or axial flow of air at high velocity carries small droplets to the target. It is used to spray large area with small quantity of the spray liquid. It is suitable for spraying ***shade or Orchard trees*** with droplet size *80-100*μ . For mosquitoes control the droplet size is 50-70 μ. Such sprayer is ***High Concentration, Low Volume*** and ***Low Pressure***. The centrifugal force of rotor determines the size of

the droplets. Here pressure is kept constant at 0.7 kg/cm^2.

Mist sprayer is used for Blast spraying and Drift spraying. In case of blast spraying, a blast of air produced by machine carries fine droplets of the spray liquid to the target. But in case of Drift spraying, the fine droplets of spray liquid are carried to the target by using the blow and direction of the wind. Large sized mist blower is grouped into stretcher or wheel barrow or vehicle mounted.

In India, an ***aircraft*** was first used to ***control mosquitoes*** in Delhi in *1944-45* and to control ***desert locust*** in *1951*.

Other Equipments :

(I) Fog generator : When the droplet size of the spray liquid is *1-50μ VMD* means smaller than that of mist, such used sprayer is called Fog generator and such fine drops are known as *Fog*. It is used to kill flying insects because droplets remain floating in the air. It is suitable for treating very dense foliage or enclosed spaces to prevent drifting. For treating larger areas in shorter times with smaller quantities of the material, Fog generator is one of the best use.

(ii) Smoke generator : Smoke producing equipment is called smoke generator. The size of smoke particles is *0.001–0.1μ* . Here slow burning pellets are used to treat greenhouse and warehouses.

(iii) Aerosol Bomb/Liquified gas aerosols : Aerosol means a fine spray ejected by pressurized can. Aerosol bomb is used by the Military group to kill mosquitoes.

(iv) Soil Fumigator/Soil injecting gun : It is used to control soil insects and soil nematodes.

(v) Dust applicator for burrows : It is used to apply dust in the burrows e.g. cyamag Foot Pump where calcium cyanide is used.

Cyanogas pump is used to kill rodents by fumigating Hydrocyanic acid gas in their burrows. Here calcium cyanide is used.

*

14 Integrated Pest Management

Introduction :

The Pesticide has an indirect role in the agricultural production because it protects the plant from insect, pest and diseases. In modern agriculture, farmers are intensively using pesticides to ascertrain high yield, but in the due course the pests becoming resistant to pesticides. The crops valued more than seven crores are damaged only due to pests in India in which weeds cause 33%, diseases 26%, insects and rodents 26%, and birds, nematodes etc. cause 15% damage. The seventy percent (70%) of the used pesticides are insecticides, 12-15% fungicides and 4-5% weedicides.

In India ninety thausand tonnes pesticides are used every year, out of which 63% are used in agricultural purposes. Insecticides valued of nearly Rs. 6 hundred crores are used in Andhra Pradesh, Karnataka, Gujarat and Punjab, out of which 76% are used on cotton, paddy, jowar and wheat crops; 10% insecticides are used on the cultivation of vegetables and fruits. A comparative consumption of insecticides in developed countries in as follows -

S.No.	Country	Per ha consumption of insecticide (in grams)
1.	Japan	10,000
2.	Europe	2,000
3.	America	1500
4.	India	400

From the above table it is evident that the consumption of insecticides in India is very less as compared to of developed countries, though there are some states vize, Punjab, Haryana, U.P., A.P., Tamil Nadu Gujarat where consumption is very high. The residue of the pesticide contaminates the food-chain and

pollutes the environment. Therefore to control insect-pests and diseases, it is advisable to go for Bio-intensive integrated pest Management by adopting Judicious use of chemicals.

Harmful Effects of Pesticides :

Repeatedly use of the pesticides contaminates soil, air and ground water in addition to crop plants and its produce. Carelessly use of such pesticides creates intensive toxicity. It's long term use affects the biological system of the animals. Such pesticides are generally known for its carcinogenic (Cancer producing) effect, tertogenic (deformity producing), tumouragenic (tumour and cyst producing) effects. The heavy and uncontrolled use of chemicals brings down the bio-diversity of natural enemies due to which epidemic of secondary pests may spread and above all these pests become resistant to pesticides. The persistent use of pesticides causes hazards to non-targeted and useful organism and thus several minor-pests may appear in epidemic form. For example in rice-ecosystem, there is 3.5 times decline and in cotton-ecosystem, there is 12 times decline in natural enemies. Previous several minor-pests have become harmful and major pests viz. Rice leaf folder ***(Canphalocrocis medinalis)***, Green leaf hopper (*Nephotettix* spp.) and white backed planthopper ***(Sogatella furcifera)*** in rice-ecosystem and old world boll worm ***(Helicoverpa armigera)*** in cotton ecosystem. Several other pests have developed resistance to pesticides at the normal doze viz. Old world bollworm *(H. armigera)* Brown plant hopper *(Nilaparvatha lugens)* of rice; diamond back moth *(Plutella xylostella)* of crucifers, black aphid *(Aphis craccivora)* of groundnut, tobacco caterpillar *(Spodoptera litura)* of groundnut and other crops, Mustard aphid *(Lipaphis erysimi)* of castor, Serpentine leaf miner (*Liriomyza trifolii*) of tomato and other crops.

Some pesticides are easily degraded and decomposed in soil after doing their works but some don't. Some are cyclic-hydrocarbon viz. BHC, DDT, Aldrin etc. in which chlorine is the main constituent. Such elements are inbibitors of the biological degradation and stop the oxidation-ring. These elements are remained in the environment for the long time.

The concentration of such materials are increased year by year. These materials are accumulated in the soil and water. From there they enter into the food-chain through producers. When vegetarians consume them as food, these harmful pesticides are deposited in their body tissues where their concentration becomes more than that of the producer. And if these vegetarians are consumed by the non-vegetarian consumers, these pesticides reach in their body where they become more and more concentrated. Moving through different levels of food-chain, these injurious pesticides are deposited in human body where their concentrations reach to the highest because man is the top consumer. Such increment in the concentration of pesticides is known as ***Biological Magnification/Bio-Magnification***. Many surveys showed that majority of the people living in the Indian cities have more amount of DDT above the tolerance level in their bodies. The more concentration of pesticides like DDT in birds decreases the thickness of egg shell as a result these eggs hatch prematurily before the complete embryo-development. For this reason, a number of aquatic birds like pelican has been decreasing day by day.

The use of different agricultural chemicals causes the effect of phytotoxicity, Pollen-sterility, pollution and developmental obstruction. Due to these hazardous effects of pesticides an awakening has been seen in the agricultural scientists and now they have been emphasised on the need-based use of chemicals and Bio-intensive integrated pest management. Now the farmers are instructed to use chemicals in the special conditions only after the recommendation when other methods of pest-control become failure.

Integrated Pest Management :

Any single measure of pest-control has never been proved effective and permanent solution. Heavy use of pesticides caused environmental problems and the residue of pesticides started to accumulate in the human body. Some pests are aclimatised themselves and developed resistant to pesticide. Presently intensive agriculture has been practiced by the farmer instead of mixed cropping and crop rotation like traditional agriculture.

Modern Farming practices viz. Monoculture, Cropping

scheme, multiple cropping, i.e. to say transformed agri-economic; induced the pest-hazards.

Therefore the need has been felt to develop such pervasive programmes of pest-management which are favourable to environment and able to control the pest-damage. Considering this concept, one policy measure has been developed which is named as 'Integrated pest Control/Management'. The term IPM was first coined by Barlett in 1956 and suggested to integrate chemical and biological control methods.

Geir and Clark (1961) modified his view and defined IPM as "Integrated pest management, briefly IPM wherein not only biological and chemical but all available methods were meant to be integrated". FAO (1967) again modified and defined as - 'a systems that, in context of the associated environment and the population dynamics of the pest species, utilise all suitable techniques and methods in a compatible a manner as possible and maintains the pest population at level below those causing economic injury. A modern definition of IPM has been given by Smith (1978) - 'A multi disciplinary, ecological approach in the management of pest populations which utilizes a variety of control tactics compatibly in co-ordinated pest management'.

According to Pedigo (1991) : - 'IPM is a comprehensive approach of pest control that uses combined means to reduce the status of the pest to tolerable level which maintaining a quality environment.'

It is evident from the above definitions that all the different pest control measures are integrated and are planned to minimise the crop-damage without disturbing the ecological system. Later on scientists feel that neither the eradication of pests is possible nor such is beneficial and keeping this view in the mind, conservation of natural enemies to pests are compulsory and thus the new name of IPM is *Bio-intensive Integrated pest Management* (BIPM). Under the BIPM the population of the pests and the population of concerned natural enemics are so co-ordinated that the pest population can not cross the line of economic injury. The objective of this

programme is to get maximum crop protection against pests at the least cost.

The measures for minimization of pest population depend upon agro-climates, land conditions, selection of varieties, local agro-economical systems and socio-economical conditions of the farmers. The conservation of natural enemies of pests and all the possible meausres are adopted under BIPM. These are as follows :-

[A] Cultural Measures :

Cultural measures means such cultural practices which do not allow the favourable conditions for life-cycle, growth and breeding of the pests. In this measures the practices like ploughing, sowing, irrigation and harvesting etc. are so managed that pest population does not cross the economic injury level. Such measures do not require special cost and input. Here following measures and practices are adopted :-

(1) Selection of site/crop : For successful production of crops and trees, it is essential to select proper field and climatic region. The selected varieties should be tolerant to the pests of that particular climatic region. For example-*Mythimna separata*, *Spodoptera mauritia* and *S. litura* are found generally in all the regions but are specially seen in flooded area of some states after the flood recedes. Citrus plants in sandy soils and waterlogged areas are more prone to pests. Ratooning of sugarcane in the gurdaspur borer *(Acigona steniella)* infested field is more prone of this pest. Irregular and unequal growth of the crop promotes the pest-infestation on smaller and younger crops.

(2) Ploughing : Deep ploughing of soil exposes the hidden eggs and pupa of insects, nematodes, rhizomes and bulbs of the persistent weeds and other organisms which become food for their natural enemies. Some birds follow the plough or tractor at the time of ploughing is the good example. Insects in the pupal stages are helpless and are easily removed and killed. Summer ploughing by soil turning plough is specially useful in this respect. The type of equipmnet used for ploughing has also a significance.

(3) Planting material : Many insect pest and diseases

are transmitted from one crop to the next crop through infested/ infected seeds or any other planting materials.

Therefore to grow new crop such certified seeds should be used which are free from all the insect-pests and diseases.

(4) Time of planting and crop duration : Adjustment in the time of sowing or transplanting helps in pest-control. Early sowing of mustard prevents from infestation of aphids. Gram sown before 15th of October shows less infestation of Heliothis. Late sowing of groundnut prevents from infestation of white grubs. Crops of the short duration give less chance to pest-infestation because these crops mature before the emergence of the pest.

(5) Destruction of off type and volunteer plants : Off type plants is impure of new variety grown during the crop-production. Such off type is more susceptible to pest which is grown along with the standard variety. Potato tubers which are remained in the soil during digging, germinate early and attract potato cutworm *(Agrotis segetum and other spp.)*. Ganganagar ageti (off type plant of cotton) is comparatively more prone to jassid *(Amrasca biguttula biguttula)* and pink bollworm *(Pectionofora gossypiella)*.

(6) Destruction of Alternate hosts : Many plants especialy weeds work as alternate hosts in off-season for insect pests and diseases. Paddy mealy bug, Army worm and fruit sucking moth spend their life on alternate hosts before attacking on main host crops. Tomato leaf curl virus multiply on parthenium.

(7) Thinning and Topping : Such practices affect the pest-population. Topping of cotton removes the eggs of *Heliothis armigera*. Sowing of cotton, maize and hybrid millets at a higher seed rate saves the crops from pest-infestation. Unhealthy and infested/infected plants are removed through thinning.

(8) Prunning and destruction of crop residues : Unhealthy and infested portions of the fruit trees and horticultural plants are removed through Prunning and are collected and burnt. Prunning in citrus plants during April and May minimises

the infestation of shoot borer. Burning of fallen leaves and stubbles in the mango-orchard kills the nymphs of mango mealy bug. Many insect-pests hibernate and hide in the crop-residues and stubbles in the cold season, later on who emerge after becoming adults. Therefore it is essential to destroy the crop residues completely.

(9) Fertility Management : The crop growth depends on the soil fertility which indirectly affects the pests. Use of phosphatic fertilizer protects from jassid *(Amrasca kerri)* in lobia and *H. armigera* in gram. Normal and excess supply of potassium protects from pest-attack where as low dose of K promotes pest-infestation. Excess of K increases the silica-content in the leaf due to which cell-wall of parenchyma and tissues containing epidermal sclerenchyma become hard and unfavourable for pest-attack. Excess application of nitrogen invites pest-attack. Use of *Azospirillum sp.* makes the plant hard against the attack of insect-pests and diseases.

(10) Water management : It is seen that in the flooded area the pests inhabiting in the soil are submerged, some are flown away and some are exposed to their natural enemies. Soil inhabiting pests like white grub and cutworm are reduced after the irrigation. The irrigation in sugarcane and wheat crop protects from white ants. The attack of aphid *(Lipaphis erysimi)* is more in rainfed mustard after 47 days of sowing in comparison to irrigated. The deficiency of normal water in the plant increases the concentration of nitrogen and soluble sucrose in the phloem-sap, due to which aphid-infestation is more.

Excess of malic acid in gram brings resistance against *Helicoverpa armigera*. Irrigation decreases the malic acid concentration resulting in more of pod-borer infestation.

(11) Crop rotation/Roto cultivation : Crop provides food for insect-pests and disease causing organisms and if the food is abundant all round the year, such pests flourish and multiply rapidly. Their abundance depends upon the fecundity, hibernation, brooding period, dissemination capacity etc. Therefore the pest problem of the specialised farming will be different from the mixed farming areas. The pest-problem of

monoculture can be controlled by adopting crop-rotation/Roto cultivation.

(12) Cropping Scheme and trap Crop : Certain pests may be controlled by using trap crops in the cropping scheme. Certain pests are more attracted towards certain crops. Such crops are sown in narrow strips arround the major crop at a specified row distance are served as a trap for the pest that might be common to both. The preferred host plants can be grown around the valuable main crop and when the pest has appeared, they can be cut and destroyed. Lady's finger (Bhindi) is an good example of trap crop for cotton to attract jassids and cotton bollworms. To attract hairy caterpillar, sesame can be grown around the cotton.

To attract diamondback moth, leaf webber and aphids of cabbage, two rows of mustard are sown after each ten rows of cabbage. One row of mustard is sown after 15 days of transplanting and another one after 25 days. When the pest appears on mustard, spraying of 0.5% dichlorvos at a interval of 10-15 days can be done and the main crop (cabbage) is to be sprayed with neem based insecticide which protects natural enemies also.

Transplanting of yellow tall marigold *(Tagets sp.)* or bidi rustica tobacco (1:5) arround the tomato is useful to control *Helicoverpa armigera. H. armigera* lays her eggs on yellow tall marigold which is exposed to egg-parasitiod *Trichogramma chilonis*. Spraying of HaNPV or Bt (HaNPV→Nuclear Polyhedrosis Virus of H. armigera; Bt → *Bacillus thuringiensis* (bacterium)] is done on the main crop of tomato which is safe to *Trichogramma. H. armigera* on rustica tobacco may be controlled by Mirid predator named *Cyrtopeltis tenuis*. In the locust *(Schistocera gregaria)* affected areas, neem trees are grown to attract predatory birds.

(13) Use of resistant varieties : It is well known that some crops are less attacked by pests because they have more natural resistance than others.They have some special characteristics like acidity or tasteless of cell sap, early maturity,

hard bark etc. which help in building their resistance.

[B] Mechanical and Physical Measures :

Such measures involves the use of physical components of environment or the use of labour with or without the help of special equipment. Such measures give quick result therefore these are popular among the farmers but it is laborious and time-consuming and not possible on large scale. The important components are as follows :-

(1) Destroying after Hand-picking : Different stages of pests viz egg, larva, pupa and insect itself are picked up regularly and are destroyed. It is the oldest method and is suitable for adults and egg cluster of lemon-butterfly, grubs of mustard sawfly and all stages of Epilachna spp.

(2) Use of net or Screens/barriers : Outlets of the farm houses viz windows, doors & ventilators are screened to prevent flies, mosquitoes, bugs etc. The net is used to cover the nursery of tomato and chilli to protect from transmission of virus through *Bemisia tabaci*. Wrapping of pomegranate fruits with butter paper or cloth protects from Anar butterfly. Wrapping of orange fruits with bamboo-baskets protects from fruit sucking moth. Coconuts are saved from monkey by planting thorny plants around the coconut plant.

(3) Temperature : Almost all the insects are inactive at the low temp. between 60^0F (15.5^0C) and 40^0F (4.4^0C) and even at the lower temp. i.e. below 40^0F (4.4^0C) practically there is no damage by the pests. But higher temp is more suitable to control the pests than the lower temp. Steam sterilisation of glasshouse kills the soil pests (insects, disease causing organisms and nematodes). Simon cotton seed heater is used to kill the larvae of *Pectinofora gossypiella* in which cotton seed is treated for 3-7 minutes at the temp. of 125 to 135^0F upto 140^0F (51.6^0C-57^0C upto 60^0C)

[Conversion formula : $\frac{C^0}{5} = \frac{({}^0F - 32)}{9}$]

Bulbs are given Hot water bath treatment to destroy nematodes and mites. Blow lamp is used to kill the colonies of wooly aphids. Seeds and grains of godown pests and due to hot air treatment moisture content of seed is also reduced resulting in the increase in storage-life of seeds/grains. The empty godown may be given superheating above 50^{0}C for 10-12 hours to kill hibernating pests.

(4) Use of mechanical traps : Light traps are used for those pests who attract towards light. Such pests are white grubs, Agrotis, rice stem borer, leaf hopper etc. Blue cloth is used to trap (polyphagous) tobacco caterpillar *(Spodoptera litura)*. Different types of traps are used to trap rats. Pheromone traps viz. Cis-9, trans-11-Tetradeca dienyl Acetate for *Spodoptera litura* and *S. littoralis*; and Cis-9-, trans-12-Tetradeca-dienyl Acetate for *Ephistia elutello* and *S. litura* are used. To control crawling insect-pests on trees, banding materials are used which are of two types- (1) Sticky band (e.g. *Ostico*) and (2) Slippery band (e.g. *Cellophane*). Greese bands are used to control mango mealy bug, wingless insects and ants.

(5) Use of Radiant Energy : High Frequency radio waves (2450 mega cycles, 12.25 cm wavelength and 940 watts) generates temp. of 170^0-187^{0}F (76.6^{0}C - 86.1^{0}C) which is used to kill hibernating or hiding pests in godown like grainery weevils and confused flour beetles within 15-20 seconds only.

Radiant energy is indirectly used to make male insects sterile. Male insects are made sterile by using γ-radiation (gamma radiation) or chemo-sterilants and are released in the normal population of insects where such sterile insects compete with the fertile males for copulation with the female. And thus population of insect-pests can be controlled. *E. F. Knipling* and Co. of USA in 1937 made the pupae of *Screw Worm fly* (*Cochliomyia homini vorax*) sterile on *Curakao island*. He used the γ-radiation by cobalt-60 (^{60}Co). Such male sterile insects were released @ 400 males per square miles to get 100% sterile egg masses and the pests were completely controlled. This technique was known as *Sterile Male* Technique and thus ***E.P.***

Knipling was the propounder of the concept of *genetic control* of insect pest.

(6) Use of drie-die : The Drie-die (prevalent in USA) is a very porous & fine silicagel. It desiccates water from the cuticle of insects resulting into death. It is used mainly for godown insect-pests.

(7) Spike Thrust method : Iron hooks are used to kill white grubs and adults of *Rhinoceros beetle* present in *Coconut-crown*. This method is spike thrust method and is also used for sugarcane stem borer and Mango stem borer.

(8) Removal of insect-pests by sieving and winnowing.

(9) Use of scintillating tapes to protect from birds.

(10) By making intense sound and shaking the pests.

[C] Biological control Measure :

In a natural or unperturbed perturbed ecological systems the insect-pests and weeds are automatically controlled by their natural enemies. But in the perturbed ecological system predators, parasites, mites, fungi or any other organisms are used in excess to control different types of pests; which is called biological control measures. Parasitoid, Predators and Pathogens are used as the natural enemies to control insect pests but parasitoids and Predators are used more.

Parasitoid : When an insect is itself a parasite, then it is called parasitoid e.g. egg parasitoids of *Trichogramma chilonis* and *T. japonicum* are used to control Tissue borers of sugarcane and Rice.

Primary parasite : such parasite attacks on phytophagous insects.

Hyperparasite : Such parasite attacks on primary parasite. Hyperparasite is also known as secondary parasite.

Autoparasite : In some species of insects it is found that male insect attacks on female insect of its own species which is called Autoparasite.

Homeostasis : Over a long time the population of pests become stable i.e. Homeostasis is the stability of pest populations

over a long time. Pest populations may fluctuate temporarily but over a long range of time, they tends to be stable.

Predators : Who hunts or kills other organisms for food, is called predator. The first insect scientifically employed for any biological control programme was ***the Vadalia beetle (Rodolia cardinalis)*** brought from ***Australia*** into ***California*** (USA) in ***1888*** to control the *cottony cushion scale (Icerya purchasi)* a serious pest of ***citrus***. However the first natural enemy to be introduced by man from one country to another was a *Mynah* from India to Mauritius in 1762 to control the red locusts. Chandra Shekhar Lohmi of India discovered a bug in 1975 which successfully controlled the *Lantana camara* a flowering weed of Nainital. This bug is known as Lantana bug. Followings are the important in biological control :

(1) Consevation of Natural enemies.
(2) To release parasite/parasitiods.
(3) Use os Microbials/Pathogens.
(4) Use of Predators.

(I) Conservation of Natural enemies :

Conservation and enhancement of natural enemies should be of first priority. If the natural enemies are properly conserved, the need of other control measures is greatly reduced. Conservation means to avoid such measures which are harmful to natural enemies and to enhance those measures which are helpful in increasing their longevity, reporduction or to build up attractive habitat. Conservation becomes most critical when there is a small reservoir of natural ememies outside the cropped area. Pupae of epipyrops are found in large numbers on the leaves and trashes of sugarcane at the time of harvesting. If these trashes/leaves are not burnt but are left around the harvested fields, the adults emerge to augment the supply of natural enemies in the premonsoon season against *Pyrilla purpusilla* on the young sugarcane crop. Cultural practices likes ploughing, mowing or burning of crop residues may be harmful to natural enemies. The concept, '**More is the diversity**, '**more**

is the stability' holds true, since diversity may provide alternate hosts as source of food, sites in winter and so on. Almost all the pesticides have adverse effect on the natural enemies. Therefore good pesticide should be used and promote such predators who are relatively resistant to such pesticides different measures are so managed that the population of predators is increased. For predatory birds and wasps, artificial nests should be available and Flowering trees having pollen and nector like Euphorbia, wild clover etc. should be planted at bunds.

(2) To release parasite/Parasitoids :

For the effective control of the particular pest, the specific parasites or parasitoids are released. This method is the most effective and economical against pests those have only one or few discrete generations in a year. Massive release have been attempted in several programmes involving natural enemies like *Trichoderma* spp. and general predators like green lace wings and *Coccinella septempunctata*.

(3) Use of Microbials / Pathogens :

The micro-organisms like bacteria, virus, reckettsiae, protozoa, nematodes and fungi have the capacity to affect the pests. ***d' Herelle*** utilized one bacterium named *Coccobacillus acridiorum* (Modern name-*Cloaca cloaca* VAT. *acridiorum*) isolated from desert locust *Schistocerca pallens* for the control of locust. However his work was not confirmed by the later scientists, though d' Herelle may be named as the ***father of microbial control***. The term 'microbial control' was coined only in 1949 by Steinhaus. *Bacillus thuringiensis* (bacteria) is very effective in controling many *Lepidopterous* larvae like cabbage worm, *Pectinofora gossypiella*, sugarcane stem borer etc. *Bacillus popilliae* causes milky disease in Japanese beetle. NPV (Nuclear Polyhedrosis Viruses) have the effective control over *Spodoptera litura* and *Helicoverpa armigera*.

(4) Use of Predators :

The coccinellid predator *Cryptolaemus montrouzieri* (Muls.) feeds on citrus mealy bug and grapevine mealy bug. The exotic coccinellid *Curinus coeruleus* Mulsant a shiny bluish-

black ladybird beetle was introduced into India from Thailand in October 1988 to control subabul psyllid, *Heteropsyla cubana* crawford. Ducks are employed to control striped bug, *Tetroda histeroides* in rice crop. The *Euglandina rose* and *Gonaxis quadrilaterlis* is employed to control Gaint African snail *Achatina fulica*. The predator *Cyrtorhinus lipidepennis* (Miridae) feeds on all developmental stages of brown plant hopper (BPH) but primarily on eggs. The wolf spider *Lycosa pseudoannulata* is also a potential predator in nature in rice ecosystem.

Due to increasing importance of biological control, many countries have now bilogical control stations that collaborate with each other to solve their pest control problem through natural enemies (biological control agents). The CIBC of India (Commonwealth Institute of Biological control) is the unit of CAB (Commonwealth Agricultural Bureau) with its headquarter at Trinidad (West Indies). The CIBC, Bangalore came into existence in 1956 and since then it has imported over 100 species of insects. The function of the Institute (CIBC) is to furnish information on natural enemies of insect pests and supervise and supply biological control projects anywhere in the world.

Table : Successful examples of Bilogical agents used in Pest Management

Natural Enemies (Biological agents)	Host (to be controlled)
For Insect Pests	
[A] Parasitoids/ Parasite	
(1) Vadalia beetle *(Rodolia cordinalis)*	To control a serious pest of citrus . Cottony cushion scale *(Icerya purchasi)*; introduced in 1888 in California (USA) from Australia.
(2) Mirid Bug *Cyrtorhinus mundulus*	To control leaf hopper of sugarcane *(Perkinsiellla sacchaicida)*; introduced in Hawaii in 1905 from Australia.
(3) Hispid beetle *Pediobius parvuls*	Hispid beetle *Promecotheca reichei*, a serious pest of coconut palm in Fiji.

(4) *Metaphycus lounsburyi*	Black scale of citrus *(Saissetia oleae)* in South Africa.
(5) Lady bird beetle *Cryptolaemus montroyzieri*	citrus mealy bug *Pseudococcus* spp. in california (USA)
(6) Egg Parasite *Opencyrtus erionotate*	Banana Skipper *(Erionota thrax)* in Hawai.
(7) *Aphidius smithi*	Pea aphids in USA
(8) *Orgilus lepidus*	Tuber moth in Australia.
In India	
(9) *Leptomastix dectylopii*	Common mealy bug *(Planococcus citri)*
(10) *Apanteles flavipes*	Sugarcane stem borer *(Diatraea saccharalis)*
(11) *Apanteles subadinus*	Potato tuber moth.
(12) *Aphelinus mali*	Wolly aphid *(Eriosorna lanigerum)*
(13) Pupal parasite	
a. *Isotima Javensis*	Sugarcane top borer *(Tryporyza nivella)*
b. *Encarsia perniciosi*	San Jose scale
(14) Larval parasite *Campoletis chloridae*	*Heliothis armigera*
(15) Egg Parasitoid *Trichogramma chilonis* and *T. japonicum*	Tissue borers in sugarcane and rice ecosystem; 8-10 release @ 50,000/ ha.
(16) *Trichogramma brasiliens*	To control Tomato fruit borer; 6 times or release @ 50,000/ha; first release *T. pretiasum* or *T. chilonis*
at 30 days after transplanting	
(17) *Trichogramma chilonis*	To control bollworm in cotton ecosystem; release @ 1,50,000/ha at 7-10 day interval during the egg laying period.
(18) *Epiricania melanoleuca*	For the suppression of sugarcane pyrilla; periodic release of 4000-5000 cocoons or 4,00,000-5, 00,000 eggs/ha
(19) *Goniozus nephantidis* or anthocorid bug *(Cardiastehus exiguum)*	To control coconut leaf caterpillar *(Opisina arerosella)* in coconut groves 1:5 parasitidi; Host ratio is released at 14-15 days intervals during peak availability of pest.

[B] Predators	
(1) *Deraeocoris indicus*	Aphids *Mysus persicae* and *Aphis gossypii*
(2) Aphidilion *(Chrysoperla carnea)*	released @ 2 larvae per plant during the peak activity of cotton bollworms and sunflower capitulum borer.
(3) Predacious mite *Phytoselulus persimillis*	Glass house red spider mite *Tetranychus urticae*
[C] Microbial/Pathogens	
(a) Bacteria	
(1) *Bacillus thuringiensis* (B.t. bacteria)	effective against the caterpillars of many Lepidoptera; extensively used; products of B.t. marketed as wettable powder, dusts, granular preparations and Flowable concen trates.
(2) *Pasteuria penetrans*	antagonistic of plant parasitic nematodes
(b) Fungi	
(3) *Metarhizium anisopliae*	Applied at the breeding sites of the *rhinoceros* beetles after pre-monsoon rains, infects pyrilla,white grubs and aphids.
(4) *Paecilomyces lilacinus*	Antagonistic of plant parasitic nematodes.
(c) Virus	
(5) Baculovirus particularly Nuclear Polyhedrosis Viruses (NPV) of *Heliothis* and *Spodoptera litura*	In pulses, NPVs of *Heliothis* and *Spodoptera litura* has promising result.
(6) NPV of *Helicoverpa armigera* (HaNPV)	*Helicoverpa armigera* on tomato and on pulses.
(7) Baculovirus infected rhinoceros	For the suppression of coconut rhinoceros beetles, release 10 baculovirus infected rhinoceros beetles per plant.
For Diseases	
(1) Fungal Pathogens : *Trichoderma harzianum*	Fungal pathogens *(Trichoderma sp. Gliocladium sp.)* screened against

T. viride *T. hamatum, T. virens,* *T. polysporum, T. Konigli,* *T.pseudo koningii,* *T.piluliferum* *Gliocladium deliquescens* *G.roseum, G. catenulatum*	*Rhizoctonia solani* (Chickpea), *Sclerotium rolfsii* (gram, sunflower groundnut) *Fusarium solani* (gram), *Fusarium oxysporum* f.sp. *ciceria* (gram), *Botrytis cinerea* (rose and gram)
(2) Bacterial Pathogens : *Pseudomonas cepacia* (strain N-24)	Effective for the suppression of *Sclerotium rolfsi* in sunflower rhizosphere.
For weeds	
Parasitoids :	
(1) *Dactylopius opuntiae*	against prickly pear *(Opuntia dilleni, O.elatior)*
(2) *Dactylopius celonicus*	against drooping prickly pear.
(3) *Zygogramma biocolorata*	*Parthenium hysterophorus*
(4) *Cyrtobagous salviniae*	Water Fern *(Salvinia molesta)*
(5) *Neochetina eichhorniae* *N. bruchi* *Orthgalumna terebrantis*	Water Hycinth *(Eichornia crassipes)*
(6) *Lantana bugs*	*Lantana camara*

[D] Chemical Control :

Chemical control measure is the most prevalent amongst the different measures of pest management. For the effective and balance use of minimum quantity of the pesticide, There are two main principles:-

(1) Use of selected pesticides

(2) Need based use of Pesticide.

(1) Use of Selected Pesticide :

Physically and biologicaly selected pesticides are desirable from environment point of view. Monotoxic chemical kills only one species of pest and does not harm to other organisms, but such chemical is discoverd very few. The main object in selecting pesticide is that the selected one must be harmless and non-injurious to beneficial and non-targeted fauna and flora. Since very few such chemicals are available, therefore such measures should be adopted which minimise the hazardous and adverse effects of the pesticides. These measures are:-

(a) The minimum amount of pesticide should be prescribed.

(b) The chemical should be selected on permanent basis but at every time the pesticide of less strength should be used.

(c) The chemicals should be used in a planned way to kill targeted pests only and not harm natural enemies.

(d) Keep the surface rough at the time of transplating so that beneficial organisms can escape in hollow places.

(e) Use the pesticide only when the pest population crosses the Threshold injury level.

(f) Only selective and non-persistent pesticides should be sprayed at soil that the natural enemies can be escaped from to come in direct contact.

Study on selective protection of recommended concentration of chemical pesticides revealed that endosulfan-22 in chlorinated hydrocarban group is comparatively safer to natural enemies. Other safer pesticides are phosalone-29, monocrotophos- 12, oxydemeton methyl-11, dichlorvos-10 under organo-phosphate group. Botanicals or biopesticides, fungicides, acaricides, and herbicides are generally safe to natural enemies.

There are about 1005 species of plants which have insecticidal properties; 384 species have antifeedant properties, 297 have repellant; 27 have attractants and 31 species have growth inhibiting properties. Neem (*Azadirachta indica*). *Pongamia globra* and Mahua (*Madhuca indica*) are well known botanical pesticides.

Extract from neem seed-kernel (2-5%) is effective against rice cutworm, diamond black moth, rice brown plant hopper, rice green leaf hoppers, tobacco-caterpillar and different species of aphids. Mahua seed kernel extract (5%) is effective against sawfly and other insects.

(2) Need based use of Pesticide :

The Strategy of a good IPM Programme advocates need based use of pesticides rather than calender based prophylactic treatments. The pesticide should be chosen on the basis of its effectiveness and least injury to useful non-targeted organisms. The pesticide formulations, application measures and time of application are also important for effective IPM Programme.

The following points are to be adopted under chemical

control measures:-

a) Essential nursery treatment so that the population of pests borne in nersery can be minimised.

b)Minimum use of pesticide.

c) Proper care of nersery so that need based pesticides can be used.

d) The pesticide should not be used on calender basis with some exception.

e) Use of proper amount of pesticide at proper time.

[E] Pest Survellance :

Pest surveillance is the fundamental tool in IPM for taking management decisions. It requires estimation of changes in the pest distribution and their abudance information about the life history of pests and influence of natural enemies; and the effect of climatic factors on pest populations. Vulnerable stages of the pest are acertained. Their programme can be taken on the basis of area or at the farm level. The use and misuse of pesticides has led to the problems of pest resistance and resurgence, distruction of beneficial organisms and wild life, pesticide residues in food, fodder and feed etc. Pesticide resistance management (PRM) is possible only when survey and surveillance of pest is carried out.

[F] Forecasting of Pest Attack :

Ecology of pests is the basis for pest management. Regular pest monitoring, survey and surveillance is necessary to enhance the preparedness of the farmers to meet the challenges. The analysis of the agro-ecosystem under which the pests and their natural enemies thrive is vital. Forecasting of pest attack is essential for planning of successful management practices. The correct forecasting depends upon the vast knowledge of biology and ecology of the pest. For the correct forecasting, following primary informations are essential:-

(a) Seasonal quantitative study

(b) Study of life-history of pest and

(c) Effect of weather and season on pests.

The seasonal quantitative study of pests reveals the ups and downs in their number (population), geographical distribution, limit of the emergence in one season. The study of life history

helps in finding out the important facts about the number of eggs laid down, place of egg-laying, time interval and food quantity taken by each instar, maturity period of female adults etc. The weather/ season directly or indirectly influences not only the crops but the population of pests their parasites, parasitoids and natural enemies also. The pest intensity from one crop to others is also affected by weather or season.

For sucessful IPM programme, the agro-ecosystem analysis on selected crops and the conduct of *Farmers' field Schools* (FFS) have been gaining importance. Farmers are trained on IPM approach on their field, rice/ vegetable fields or orchards to gain knowledge and skill as to how to grow healthy crops and to manage pests. Such schools are called Farmers' field schools.

[G] Quarantine Measures :

The method of exclusion of the pests, enforced through certain legal measures is commonly known as quarantine. Introduction of foreign pests is possible when agriculture produce, seeds, fruits and goods are imported. Partherium weed came into India with the import of mexican wheat. Due to lack of quarantine, the spread of following pests could be possible:-

Table : Introduction of pests from one country to other

S.No.	Name of pest	Introduced From	Introduced to	Year	Remarks
Insct-Pests					
(1)	Grape Phylioxera *Phylloxora vitifollae*	USA	France	--	destroyed French vineyard
(2)	Mexican boll weevil *Anthonomus grandis*	Mexico/Ce-ntral America	USA	1892	extensive damage to cotton
(3)	European corn borer *Ostrinta nubilalis*	Italy/ Hungry	North America	--	reached probably through broom corn; became major pest
(4)	Pink boll worm *Pectinophora gossypiella*	native of India	Worldwide	--	highly destructive pest in nearly about all cotton growing areas of the world
(5)	San Jose Scale *Aspidiotus perniciosus*		India		1920s Pest of apple
(6)	Potato tuber moth *Gnorimoschema opercullela*	Italy	India	1900	Field and Storehouse pest of potato all over the country

(7)	Wolly aphis *Eriosoma lanlgerum*		India	--	Serious Pest of apple.
(8)	Fluted Scale *Icerya purchasi*	native of Australia (through Ceylon)	India	1928	introduce through Ceylon (Sri Lanka) serious pest of Citrus Spp.
(9)	Golden nematode of Potato/Potato eelworm/ Potato cyst nematode *Heterodera rostochiensis* or *Globodera rostochiensis*	-----	India	After Indepen -dence	Before 1973, Globodera was know as Heterodera
		Diseases			
(10)	Leaf rust of Coffee *Hamalleia vastartix*	SriLanka (Ceylon)	India	1876	Causal Organism-*Hemileia vastatrix*.
(11)	Fire biight of apple and Pear *Erwinia amylovora*	England	India	1940	Serious disease in Uttarakhand
(12)	Flag smut of wheat *Urocystis agropyri*	Australia	India	----	Spread in Punjab, Rajasthan, U.P.
(13)	Bunchy top of Banana (Viral disease)	Sri Lanka	India	1940	Serious damage to dwarf cavendish variety.
(14)	Wart of Potato *Synchytrium endobioticum*	Holland	India	1952	----
(15)	Onion Smut *Urocystis cepulae*	----	India	--	------

The pests problem also arises due to the transport of agricultural produce from one region to another. To stop the spread of such pests, the establishment of domestic quarntine is essential. For example the apples grown in the Kargil and Ladhakh areas of Jammu & Kashmir are not sent to outside because these areas are habitat of codding moth (*Cydia pomonella*). And due to such domestic quarantine the apple-industries of H.P. and Kashmir valley are protected from the damage caused by such pests. Domestic quarantine is implemented for the following pests-

Table : Domestic Quarantine for Pests

S.N.	Name of Pest	Infested area from where transport and movement of host plants prohibited
1.	**Fluted Scale *Icerya purchasi***	Tamil Nadu, Karnataka, Kerala
2.	San Jose Scale ***Aspidiotus perniciosus***	Punjab, H.P. Jammu & Kashmir, U.P. West Bengal, Assam, Orissa
3.	**Codling moth *Cydia pomonella***	Ladhakh and Kargil areas of Jammu & Kashmir
4.	Golden nematode of potato/patato eelworm/potato cyst nematode ***Heterodera rostochiensis*** (before 1973) or ***Globodera rostochiensis***	Nilgiri hills, Tamil Nadu
5.	**Bunchy top of banana** (Viral disease)	Assam, Kerala, Orissa, West Bengal
6.	**Banana mosaic** (viral disease)	Gujarat, Maharastra
7.	**Potato wart *Synchytrium endo -bioticum***	Darjeeling district of West Bengal
8.	**Cotton leaf curl** (Viral disease)	Areas of Punajb & Rajasthan bordering Pakistan

[H] Varietal Control :

Selection of the reistant varieties is an important component of I.P.M. It is essentailly a preventive measure.The use of resistant varieties is the cheap and the best measure of pest control. Gall midge and Brown plant hopper of Rice, Borer and scales of sugarcane, wheat rust, downey mildew of coarse grains, pulse viruses etc. have been controlled by the use of their concerned resistant varieties. Development of High yielding and pest resistant varieties are gaining importance throughout the world.

Varietal resistance against the insect pests is grouped into four categories:-

(1) Tolerance (2) avoidance

(3) non-preference (4) antibiosis

(1) Tolerance : In case of tolerance, the host plant is attacked by pests but there is little or no loss in biomass production or yield. Tolerance is mainly dependent upon growth capacity of the plant and the growth capacity is affected mainly by favourable conditions. In some cases, tolerant varieties show greater recovery than susceptible varieties from pest damage. It is generally found that the attack of shootfly, stem borer or cutworm in germination stage aggravates their growth. The tolerance may be due to ability of the host to suffer less damage by the pest e.g. aphids in sugarbeet and brassica, greenbugs in cereals. Thus the use of tolerent varities of agriculture is useful.

(2) Avoidance : Pest avoidance (or disease escape) refers to the freedom of susceptible host varieties from the pests purely due to environmental factors. Avoidance may be a result of environmental factors, early varieties, changed date of planting, change in the site of planting, use of resistant root stocks, balanced application of NPK, control of pest carriers and control of pest itself. Early maturing cotton varieties may escape from pink bollworm infestation. Early sowing of mustard varieties escapes from aphid infestation.

(3) Non-preference : Some varities are unattractive or unsuitable for colonization, oviposition or both by the insect pest. This type of resistance is also known as ***non-acceptance*** and ***antixenosis***. Non preferance involves various morphological and biochemical features of host plants. Female insect does not lay eggs on non-preferrred plant.

(4) Antibiosis : Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and /or reproduction of insect-pest. In other words the lethal or harmful effect of plant on the biosis (life) of the insect-pest is known as antibiosis. Such plants have characteristic features like hard and thick epidermis, hairy stems and leaves and above all the plant may be toxic. The morphological physological or biochemical features of the host plant either individually or in

combination may attribute to antibiosis.

The capability of the disease resistance in plants is expressed in three ways i.e. the type of disease reisistance:...

(i) Disease escape/pseudo-resistance : Some crop varieties complete their life cycle before peak period of infection due to their characteristics of fast growth and earlier maturity. And thus such varieties escape from the development of lebilitating attack by disease causing organisms; Therefore it is called pseudo -resistance and escaping from the disese is Disease escape. For example Early variety of wheat escapes from heavy damage by rust. Early variety of potato escapes from the disesae caused by *Phytophthora infestans* because attack of this disease occurs after the harvest of early potato. The crop in young or seedling stage is very susceptible whereas the fully developed and matured crop is unaffected which is known as ***Mature Plant Resistance.***

(ii) Resistance : Resistance is the ability to withstand (insect-pests and) diseases which may be conditioned by a number of internal and external factors operating to reduce the chance and degree of infection. In resistant variety, disease symptoms do develop and the reproduction rate is never zero (i.e. r#0) but it is sufficiently lower than one (i.e $r < 1$). It means the development of disease in the resistane variety is very less which is expressed in the term of reproduction rate of pathogen i.e:-

$$0 < r < 1 \quad \text{or} \quad 1 > r > 0$$

(iii) Immunity: The inability of parasite to infect the host even under most favourable conditions is known as immunity. The state of immunity is the absolute where the crop (host) is fully protected from infection. In other words such immune varieties neither allow the pathogen to develop nor show any disease symptom. Here the reproduction rate of pathogen is zero (i.e. $r = 0$) which is called ***Absolute Resistance.***

According to van der Plank (1963) Resistance is of two types on the basis of physiological differences:-

(a) Vertical resistance/perpendicular resistance/ Racial resistance: It is also known as race-specific, pathotype (biotype) specific or simply specific resistace. In this type, the

resistance is effective against only one or some specific pathotypes or biotypes. It is generally determined by major genes (oligo-genes) and is known as pathotype specificity. Due to oligogenes, resistance is only for avirulent pathotype. In case of occurence of frequent virulent pathotype, epidemics are common.

(b) Horizontal resistance/Field resistance : It is also known as race-nonspecific, pathotype non- specific, partial resistance, General resistance. This type of resistance is effective against all the known biotypes or pathotypes. It is determined by polygenes i.e. many genes with small effects. Here reproduction rate is not zero but it is less than one i.e. $r > 0$ but $r < 1$. It means the symptoms of the disease appear but the rate of spread is slow.

(1) Male sterile Technique :

Male Sterile technique of pest control is known as genetic control under autocidal technique. The concept of genetic control was conceived by E.F. Knipling. For detail see 'the use of radiant energy'. For making male insects sterile, γ-radiation obtained from cobalt -60 and chemo-sterilants are used. Chemo -sterilants are mainly derivatives of strong alkylating agent Aziairidine. TEPA [tris (1-aziridinyl) phosphine oxide] METEPA [tris (2-methyl 1-aziridinyl) Phosphine oxide] and Apholate [2,2,4,4,6,6, hexahydro-2,2,4,4,6,6.-hexakis (1-aziridinyl)-1,3,5,2,4,6-triazatri-phosphorine] are common alkylating agents. Male sterile insects made by radiation have shown less sexual competiveness whereas steriles made by chemosterilants have shown increased sexual competitiveness. Successful examples of male sterile technique by radiation are in fruitflies, Oriental fruit fly-*Dacus dorsalis* and Mediterranean fruit fly-*Ceratitis capitato*. Upto some extent this technique has been used is melon fruit fly (*Dacus cucurbitae*), Onion fly (*Hylemya antigua*) cotton boll weevil (*Anthonomus grandis*) cockchafer (*Melolontha vulgaris*) cabbage looper (*Trichoplusia sp.*) Corn earworm (*Heliothis zea*), gypsy moth, codling moth (*Laspeyresia pomonella*) Chemosterilants have been successfully used in cotton boll weevil, red bollworm (*Diparopsis castane*) Pink boll worm (*Pectinophora gossypiella*) to produce male sterile. Male

sterlie made by TEPA has been successfully employed to control mexican fruit fly *(Anastrepha ludens)*.

[J] Use of IGR, Pheromones, Attractants & Repellants.

Juvenile harmone and chitin inhibitors are examples of IGR (Insect Growth Regulator) which affect insects only. Juvenile hormone (J H) inhibits developing adult insect under the pupal stage. JH is effective even if it is applied on the cuticle of pupa. It is secreted by corpora allata. Williams (1967) suddenly observed JH in the stomach of male Cecropia moth which has been chemically known as Neotenin. This hormone when sprayed on the target insects at the suitable stage, affects the metabolic activities and produces disorder in their reproduction and development resulting into death of the insects. Since it does not kill instantly, therefore it is not suitable to use at the time of outbreak of pests. Altoid, Kinoprene, Altozar etc. are commercially major IGR. Chitin synthesis inhibitor and Azadirachtin like phytochemical are proved good IGR.

'Pheromones' are such chemical substances produced by an organism exogenously which influence the behaviour or physiology of other member of its own species. Pheromones are grouped as :–

(i) Sex pheromones: such pheromones attract opposite sex.
(ii) Trail pheromones: such activate others to follow.
(iii) Aggregation pheromone: to get aggregation response
(iv) Alarm pheromone: to alarm

The word 'pheromone' was coined by Karlson and Butenandt in 1959 for a chemical that is secreted into the external environment by an animal and that elicits a specific response in a receiving individual of the same species. It is also called 'ectohormone'.

Semiochemicals are those signalling chemicals that an organism can detect in its environment which may affect the organism's behaviour or physiology. Phermones are those that act between members of the same species whereas allelochemics are those that act between species. The allelochemics may be allomones, which favour the emitter, or kairomones,which favour the receiver. Many allelochemics act both as an allomone and a

kairomones. Such chemicals are called synomones. Allomone is a substance produced by an orgnaism that, on contact with an organism of another species, induces a response favourable to the individual that produced the substance e.g. the neotropical social wasp *Mischocyttarus drewseni* applies a secretion to the stem of its nest that repels foraging ants. Kairomones are such volatile compounds which evoke behavioural response adaptively favourable to the receiver. Kairomones are secreted by host plant and host insects. The Kairomones secreted by host plant are used by the pests for their own benefit and the Kairomones secrted by the host insects are used by the natural enemies for their own benefit. The Kairomones secreted by host plant may be used as pest trap in the survey of the pest.

In the normal cases, the sex pheromone produced by the female acts as attractant and produced by male acts as aphrodiasiacs (i.e. to prepare female for copulation) The chemical nature of some sex pheromones have been discovered e.g. sex pheromone of Gypsy moth has been identified and synthesized as Cis-7, 8-epoxy-2 methyloctadecane. Pheromones are used in two ways:-

(a) used as a luring agent.

(b) by breaking normal mating behaviour i.e. intersexual communication system of the pests.

Attractants and Repellants are also used in pest control. Geraniol and engenol to trap japanese beetle *(Popillia japonica)* and Siglur to trap Mediterranean fruitfly are used as attractants. To repel cockroach N, N-diethyl-m-toluamide 2-hydroxy-n-octyl sulphide as repellant is used. Some chemicals like DTA [(4' - dimethyltriazeno) acetianilide], Fentin acetate (fungicide) are used as antifeedants. Natural Pyrethrin has the property of antifeedant. Antifeedants are such substances which inhibits from pest attack without killing or repelling the pests. These are also called feeding deterrents and rejectants. The pest dies slowly due to starvation. The crop or any material treated with such chemicals becomes antifeedant.

*

15 Stored Grain Pests

The important pests causing damage to stored grains are Insect pests, Micro-organisms and rats:

The important insect pests which infest stored food grains are following :

S. No.	Common Name of insect pest	Genus	Species	Family	Order
1.	Rice Weevil	*Sitophillus*	*oryzae Linn.*	Curculionidae	Coleoptera
2.	Khapra beetle or Wheat Weevil	*Trogoderma*	*granarium Evert.*	Dermestidae	Coleoptera
3.	Rust red flour beetle	*Tribolium*	*castaneum* Herbat	Tenebrionidae	Celeoptera
4.	Lesser grain Borer	*Rhizopertha*	*dominica Fab.*	Bostrychidae	Coleoptera
5.	Pulse beetle	*Callosobruchus*	*chinensis Linn.*	Bruchidae (Lariidae)	Coleoptera
6.	Mung dhora	*Callosobruchus*	*analis*	Bruchidae	Coleoptera
7.	Saw-toothed grain beetle	*Oryzaephilus*	*surinamensis* Linn.	Cucujidae	Coleoptera
8.	Rice moth	*Corcyra*	*cephalonica*	Galleriidae staint.	Lepidoptera
9.	Angoumois grain moth	*Sitotroga*	*cerealella Cliv.*	Gelechiidae	Lepidoptera
10.	Almond moth	*Ephestia* (Cadra)	*cautella Walk.*	Pyralidae	Lepidoptera
11.	Indian meal moth	*Plodia*	*interpunctella* Hubener	Phycitidue	Lepidoptera

(1) Rice Weevil

Food : All types of Cereals

Damage : Adult and Larvae both attack grains suddenly and irregulary and eat them. Maximum damage is done in the month of August to October.

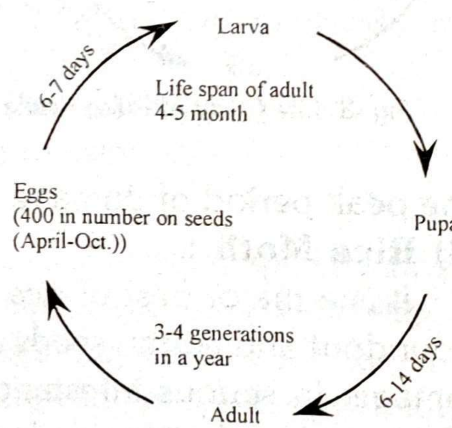

Fig.-1. Life Cycle of Rice Weevil

(2) Khapra beetle :

Damaging stage is larva only.

Though it is a major pest of stored wheat grains but it infests Jowar, Bajara, Maize, Rice etc. also sometimes infestation is seen on gram, Pea and urd also. Generally the superficial layer (50cm) of stored wheat is only attacked and embryo part of the seed is damaged, hence the seeds become unfit for sowing and consumption. Maximum damage is done during July to October.

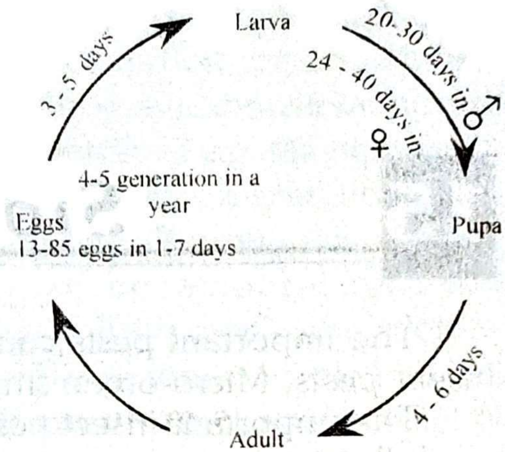

Fig.-2. Life Cycle of Khapra beetle

(3) Pulse beetle :

Only grub is responsible for damage, though it is a major pest of gram and cowpea but it feeds on other pulses also. Except the external shell all parts of grains are eaten up by the grubs.

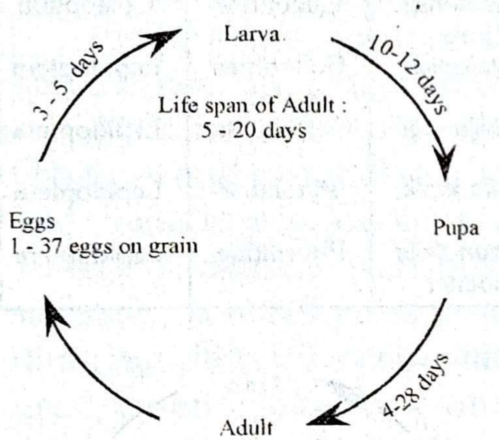

Fig.-3. Life Cycle of Pulse beetle

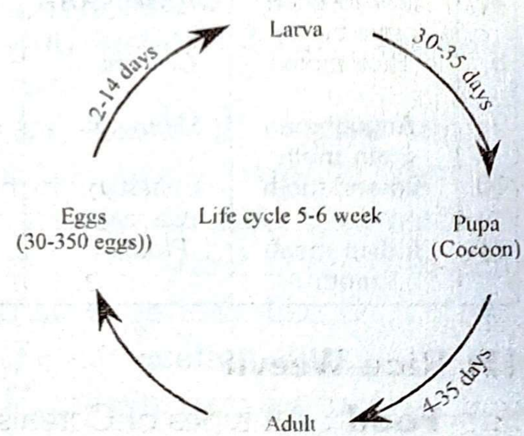

Fig.-4. Life Cycle of Rice moth

The peak period of damage is during April to October.

(4) Rice Moth :

It is a major pest of rice but it infests Gram, Jowar, Maize, groundnut and cotton seeds also. The larvae are responsible for damage. In serious infestations the godown turns in Webbed silken mass and gives unpleasant smell.

(5) Lesser grain borer : Damaging stages

are adult + grubs.The strachy materials of grains are eaten up. The young grubs are unable to pierce the grains hence they eat waste flour.

(6) Rust Red Flour bettle :

It feeds on damaged and broken grains only hence called secondary feeder. It produces pungent smell.

(7) Angoumois grain moth :

The grubs are responsible for damage. The females lay eggs on earhead in fields and after hatching minute larvae enter into the grains thus they reach in godowns and increases in number there. Their presence in godowns is always seen but maximum damage is done during the months of July to October.

Protection of Stored grain :

For it there are two basic principles :

(i) At the time of storage the grains must be completely free from pest infestation/infection.

(ii) And the grains should be stored on such a place where the chances of infestation/infection are minimum.

The damage to stored grains depends mainly on three factors –

(i) Moisture content of the grains to be stored.

(ii) Availability of Oxygen (O_2) in storage

(iii) The development of temperature gradient.

The storage structure, construction, design and method of storage affect the above factors :

For the control of stored grain pests two measures are adopted.

Preventive measures (Before Pest infestation)

Curative measures (After pest infestation)

Preventive Measures :

From the protection of insect pests infestation, seed treatment should be done before sowing. Balanced and clean cultivation is also necessary so that not a single seed may become the carrier of infestation upto godown. The moisture content of seed/grain at the time of harvesting must not be more than **14%**.

(a) Hygenic Measures :

(i) Threshing yards should be away from granaries and should be clean.

(ii) Gunny bags should be insect free.

(iii) All the cracks, crevices, holes existing anywhere in godown should be closed with cement or mud.

(iv) White washing is necessary before storage.

(v) Before storage the store should be disinfected by spraying Malathion 50% E.C. with dilution of 1:100.

(vi) Do not store infested/infected seed without proper treatment.

(b) Physical Measures :

(i) Drying of grain : Where the grain ha moisture content below 9% most of the insect species do not survive/ multiply except *Trogoderma granarium*. In our country the grains are dried by spreading a thin layers of grains in the sun before storage. Dryers are also used nowadays. The model moisute content for storage is **8%.**

(ii) Heat treatment : Most of the insects die at 55^0C to 60^0C in 10 minutes.

(iii) Mixing of inert dust : Mixing of dust with grains like sand, clay, ash etc. makes the entry of insects in grains a difficult task and cause physical injuries to the insects.

(iv) Use of centrifugal force, x-rays, ultrasonic waves, atomic energy, aeration, cold treatment etc. are also there but they are very costly and out of reach to the farmers.

(v) Use of completely dried and infestation free grains for storage. Keep the storage damp proof, airtight, heat resistant and termits and rat proof. For keeping the grains use aluminium bins, steel bin, plastic bins or Pusa bins etc.

(vi) Refrigeration : Most of the pests does not multiply at less than 10^0C. The growth of mites is stopped at 0^0-10^0C and below 60% Relative humidity (RH). Most of the fungal growth and spore germination do not occur at 0^0-10^0C temp and below 65% RH.

(vii) Sometimes moisture content of stored grains is more than required which creates heating effect of moisture and there is possibility of decaying of grains. Therefore dry air is blown through the grains.

Chemical Measures :

(i) Malathion 50% E.C. is used as a Spray in ratio of 1:100 with water on grain bags, walls, floors, etc. @ 3 litres/100sq. metres.

(ii) DDVP or Dichlorvos 100% EC has properties of quick knock-down and high vapour density. It is applied @3 litres/100sq. metres surface in ratio of 1:300.

(iii) Food grains for seed purposes can be mixed with some insecticidal dusts like camphor, napthalene, etc. Dried neem leaves, tobacco pyrethrum dust and derries root dust have also been used.

Curative Measures :

(i) Drying of infested grains in the sun.

(ii) Few infested grains should be screened.

(iii) Wheat weevils stick to the gunny bags kept on upper layer of wheat seed, remove them with bags and destroy.

(iv) Spreading of sand on grains (5 cm deep) prevents egg laying.

(v) By sieving and winnowing the grubs of *Tribolium castaneam* and *Trogoderma granarium* may be separated and destroyed.

(vi) The superficial layer of rice infested with rice Weevil can be controlled by Pyrethrum aerosol.

(vii) The hidden insects are killed by generating 50^0- 70^0C for 10-12 hours in storages. Simon cotton seed Heater is used to kill hidden larvae of *Pectinofora gossypiella* for generating 125 – 135^0 F for 3-7 minutes.

(viii) Radiations are also used to kill insects and micro organisms. The first γ-garden in India was established at Kolkata and 2^{nd} at Mumbai where γ-radiation is used for multipurpose.

(ix) Most practicable and useful method is fumigation. Some of the effective fumigants are given below :

Aluminimum Phosphide (Celephos) :

It is available in form of tablets of 3 g each packed in sealed tubes. The active ingredient is phosphine gas (PH_3). It can be used for all food grains, milled products etc. 2 tablets are used for 10 quintal grains.

Methyl bromide-

It can be used @ 3.5 kg/100 m^3 for 10 to 12 hours.

Ethylene Dibromide (EDB) –

It is used @3 ml ampule for 1 quintal grain and 18 ml. for 5q. and 30 ml for 10q.

The above fumigants can be used as preventive measures also. Rat traps for rats can be used in godowns.

*

16 Insect Pests of Some Crops

Most of the insect pests which cause damage to crops belong to the order Lepidoptera.

Insect pest of Paddy Crop

S.N.	Common Name of insect pest	Zoological Name	Family
1.	Rice gundhibug	*Leptocorisa varicornis*	Corcidae
2.	Rice gall midge	*Pachydiplosis oryzae*	Cecidomyiidae
3.	Stemborer (Yellow)	*Tryporyza incertulus*	Pyralidae
4.	Army Worm	*Mythimna separata*	Noctuidae
5.	Rice green leaf hopper (Jassids)	*Nephotettix viruscence*	Jassidae
6.	Rice hispa	*Dicladispa armigera*	Hispidae
7.	Kharif grasshopper	*Hieroglyphus banian*	Acrididae
8.	Swarming caterpillar	*Spodoptera mauritia*	Noctuidae
9.	White leaf hopper	*Tettigella spectra (Cicadella)*	Cicadellidae
10.	Paddy leaf roller	*Cnaphalocrosis medindis*	Pyralidae

Rice gundhi bug (Rice earhead bug) : The pest emits pungent smell.

Both nymphs and adults suck up the sap from the grains at the milky stage. Infested earheads become *chaffy*

Management :

Use of light traps.

Collection of and destruction of pest.

Destruction of weeds to remove alternate hosts.

Dusting of Carbaryl 5 per cent or Malathion 5% @ 25 kg./ha.

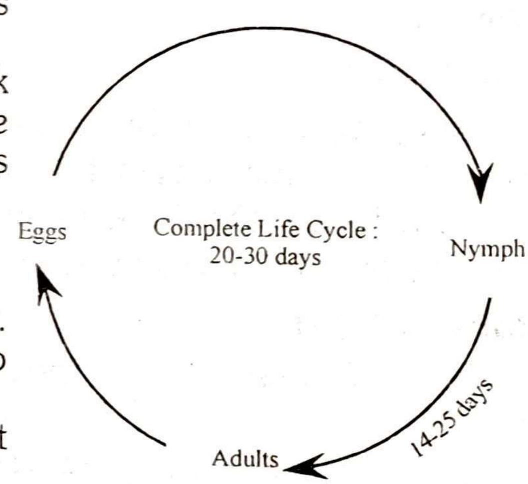

Fig.-6. Life Cycle of Gundhy Bug.

Rice gall Midge/Fly :

The maggots of pest pierce at the growing point of the plant and form a gall. The affected tillers become hollow pink or purple, dirty white or pale green cylindrical tube bearing at their tips a green reduced leaf blade complete with ligules and auricles. The gall is modified leaf sheath. The damage of this pest is characteristically known as ***'Silver Shoot'*** or **onion shoot** or **Silvery galls** since it produces long tubular gall of silvery appearance. For its management spraying of 0.05% phosphomidon, 0.02% Dimethoate, 0.2% Carbaryl 0.05% Diazionon can be done at the vegetative stage of the plants at the interval of 20 to 25 days. Granular insecticides like phorate can be applied in standing water at the rate of 1 kg/ha.

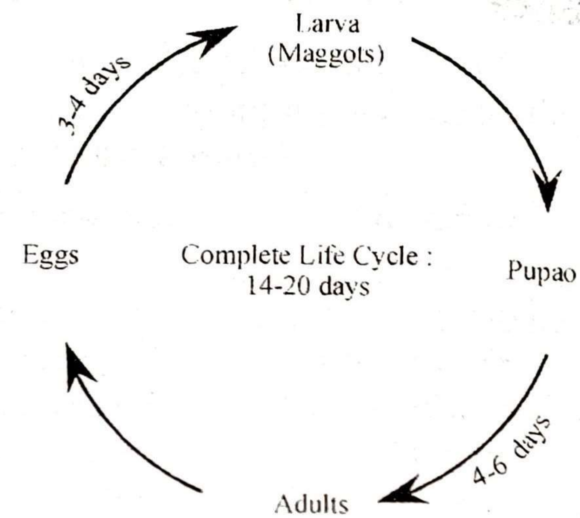

Fig.-6. Life Cycle of Rice gall fly

Yellow stem borer :

The damage is caused by caterpillars as a result ***'Dead Heart'*** formation takes place before flowering and after flowering ***'White Ear Head'*** (WEH) develops. The earheads dry up and no grain formation takes place. Basmati varieties suffer heavy damage than coarse varieties.

Management :

Clipping of tips of Seedling before transplanting, Removal & destruction of stubles at first ploughing. Fields showing more than 5% 'dead hearts' should be sprayed with 625 ml of phosphamidon or 1.4 litres of monocrotophos or 2.5 litres of chlorpyriphos.

Plant Hopper :

White Backed Plant hopper (WBPH) attacks in early crop season.

Brown Plant hopper : Attacks in later crop season.

Both the hoppers suck up the sap from plant and cause a

serious damage. They also emit a toxin into the plant which produces a particular sympton known as *'Hopper Burn'*.

Brown Plant hopper transmits ***'grassy stunt virus'*** (GSV) to the plants.

Green leaf hopper (Jassidae) suck up the sap from leaves and transmits **'Tungro virus'.**

Insectpest Management of Rice :

In India paddy is grown in different climatic regions. So insect pest management adopted by farmers changes according to cropping system and climatic regions. For various environmental regions and cropping systems different management packages have been developed which includes clean cultivation and field sanitation, wide spacing of crop plants, in timely growing of nursery and transplanting, proper crop rotation, water and fertilizer management, preventive seedling root dip, use of resistant varieties, conservation of natural enemies and judicious use of pesticides.

Weeding, destruction of weeds and alternate host plants are important components of clean cultivation.

Ploughing of fields and bunds after harvesting destroys the egg of greenhoppers. The eggs are exposed to sun light and natural enemies for destruction.

Removal and destruction of stubles helps in destruction of hiding insect pests.

Resistant varieties have been developed by scientists for different insect pests. e.g.

For Brown Plant Hopper –

Chaitanya, Vajram, Sonasati, Jyothi and Bharatidason –

For gall midge –

Phalguna, Suraksha, Abhaya

For Yellow stem borer –

Vikas and Sasyasree (moderate resistant)

For Rice Tungro virus –

Moderate Resistant : Vkramarya, Suraksha

Resistant variety LET- 9994

Natural Enemies :

For stem borer	–	Testrastichus, Telenomus and Trichogramma.
For Brown Plant hopper	–	Dryinds, entomofagous

fungi, Mirid bug.

For Leaf folder – Trichogramma, Apanteles, Brachymeria, Goniozus, Elasmus and Trichana etc.

For Gall midge – Platygaster

For control of yellow stem borer, clip the top portion of seedling before transplanting and destruction of eggs, destruction of stuble, ploughing and flooding of fields, crop rotation with non-graminaceous crops, use of tolerent and resistant varieties etc. are also helpful in management of the pest. When 50% dead heart at flowering stage and one moth or one egg mass/m^2 are seen, use of *Trichogramma japoncium* @50,000/ha/week at the interval of one week six time is useful. If necessary safe insecticide can be used. For monitoring yellow stemborer sex pheromone is useful.

Timely transplanting, proper use of fertilizers and spacing (20 cm x 15cm) is helpful in reducing hopper population. When number of hoppers reaches at ETL (Economic Threshold Level) Mirid bugs are released and according to need pesticides can be used.

To control Rice Tungro Virus (RTV) its carrier green leaf hopper should be controlled and resistant varieties should be used.

Following insecticides are effective in paddy fields –

As Granular : Carbofuran, phorate, Diazinon, Mephosfolon, Quinolphos. MICP and Cartap etc.

As Spray : Chlorpyriphos, Dicrotophos, Monocrotophos and phosalone etc.

From the point of view of bio-diversity and environmental protection minimum use of insecticide is good. For this a cheap technique has been developed which as under –

Soaking of germinated seeds for 3 hours in 0.2% chlorpyriphos or Isofenphos prevents infestation of gall midge.

Dipping of seedling roots before transplanting for 12 hours in 0.02% chlorpyriphos + 1% urea for 3 hours prevents infestation of stemborer, gall midge, whorl maggots etc. for at least 25 to 30 days.

Use of carbofuran in rootzone of plants prevents infestation for long period. For prevention of gall midge and stem borer urea coated with carbofuran is used in root zone of the plant.

In rainfed upland paddy carbofuran @2 kg a.i./ha can be used

in furrows to prevent pests.

In rainfed low lands mix carbofuran in soil before trasplanting and spray monocrotophos or quinalphos if necessary to prevent stemborer and leaf folder.

Insect pests of Cotton

S. N.	Common Name	Zoological Name of insect pest	Family
1.	American bollworm	*Helicoverpa armigera*	Noctuidae
2.	Spotted bollworm	*Earis fabia*	
		Earis vittella	Cymbidae (Noctuidae)
3.	Pink bollworm	*Pectinophora gossypiella*	Gelechidae
4.	Red cotton bug	*Dysdercus hoenigii*	yrrhocoridae
5.	Cotton Jassids	*Amarasca biguttula biguttula*	Cicadellidae
6.	Cotton white fly	*Bemisia tabaci*	Aleyrodidae
7.	Cotton leaf roller	*Sylepta derogata*	Pyrolidae
8.	Cotton aphid	*Aphis gossypii*	Aphididae

American bollworm :

In America it is a serious pest of cotton but in India it damages gram, red gram, tomato and many other crops. In our country suddenly in 1977-78 it started damaging to cotton and in 1987-88 it seriously damaged cotton in Andhra Pradesh.

Spotted bollworm :

The caterpillars damage young seedlings bud and boll. The affected bolls open prematurely and thus the quality lint is lowered.

IPM in Cotton :

Of the total insecticide used in agriculture more than 50% is used on cotton only. About 35 to 60% of the total cost of production in cotton is spent on pest control. In many parts of India pest control of cotton today also is completely dependent

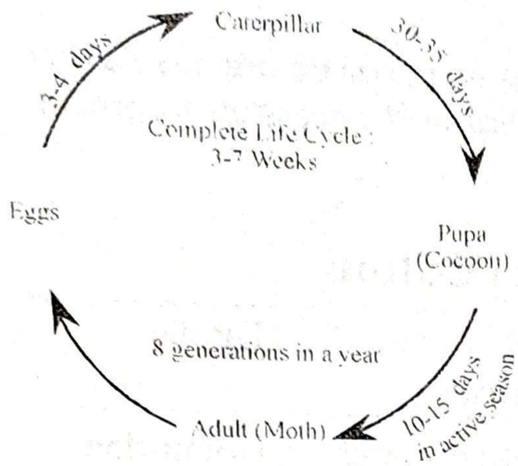

Fig.-7. Life Cycle of Amrican Bollworm

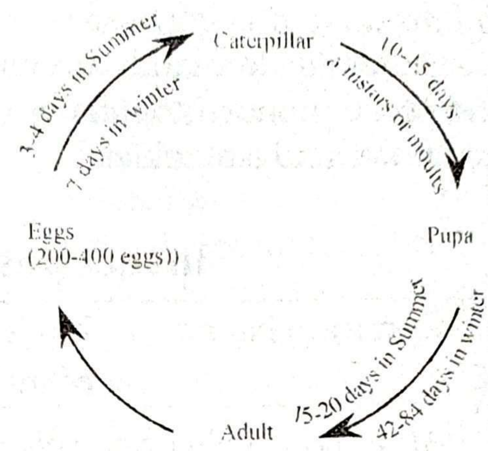

Fig.-8. Life Cycle of Spotted Bollworm

on insecticides that causes upset in environment, kills natural enemies, originates secondary pests and pesticides are becoming uneffective. For example during 1983-87 cotton white fly and during 1977-78 American bollworm became major pests of cotton. Hence keeping the above points in view a package of management practices has been evolved which includes clean cultivation/field sanitation, use of resistant varieties, destruction of crop residues, mechanical control, crop rotation, trap cropping, pest monitoring by using pheromones, protection and timely release to natural enemies and use of soft chemicals depending on ETL.

IC-1030, RKR 4145, KG9-18, S8/3 genotype are tolerent to bollworms and IC-625, SRT-1, B-1007 are resistant to jassids. Young bolls of *Gossypium arborium* have more amount of condensed tannin hence this genotype is resistant to bollworms. Condensed tannin is also more in pigmented lines which is attractive for bollworm. Prevention from sucking pests-

(i) Wider spacing

(ii) Less use of nitrogenous fertilizers

(iii) Don't have mixed cropping of cotton + Lady's finger. Cotton + Moong bean has less infestation of jassids.

Measures for Bollworms protection :

(i) Crop rotation of cotton with non-prefered crops like Ragi, Maize and Jowar etc.

(ii) Destruction of alternate hosts.

(iii) Adjustment in time of sowing according to need.

(vi) Hand picking of flared up squares and damaged fruiting bodies and their destruction.

(v) Sowing of cotton + cowpea encourages coccinellid predators and other natural enemies.

Castor is a good trap crop for *Spodoptera litura.*

In IPM production of Trichogramma and Chysoperla in large scale, their release in fields and use of biopesticides like NPV (Nuclear Polyhedrosis Virus) is necessary.

(i) Field release of predator *Chrysoperla carnea* 45 and 60 days after sowing : 50,000/ha and again after 130 days : 100,000/ha is very useful for the control of sucking pests like, Aphids, whiteflies, Jassids and thrips.

(ii) For the control of bollworms release of *Trichogramma chilonis* @1,50,000/ha/week starting from the bud formation stage of the crop is equally effective as chemical control.

(iii) If number of Helicoverpa reaches at ETL (means if it is seen 7 second stage larva/20 plants), spray biopesticide Ha-NPV @250LE/ha with 0.5% jaggery + 0.1% detergent.

(iv) Spray solution of Gossyplure gives effective control for pinkbollworm.

(v) For the effective control of cotton bollworms and sucking insects 0.5% Neem oil + 0.1% teepal and Neem seed Kernal extract (NSKE) is used.

(vi) 0.5% Neem oil + 2% mineral oil + 2% fish oil and resin soap reduces the number of white flies.

Insect pests of Sugarcane

S.N.	Common Name	Entomological Name	Family
1.	Sugarcane leaf hopper	*Pyrilla purpusilla*	Fulgoridae
2.	Sugarcane root borer	*Emmalocera depressella*	Pyralididae
3.	Sugarcane shoot borer	*Chilo infuscatellus*	Cramidae
4.	Sugarcane top borer	*Tryporyza nivella*	Pyralididae
5.	Sugarcane white fly	*Aleurolobus barodensis*	Aleurodidae
6.	Gurdaspur borer	*Bissetia steniella*	Pyralididae
7.	Stalk borer	*Chilo auricilius*	Pyralidae
8.	Sugarcane mealy bug	*Saccharicoccus sacchari*	Pseudococcidae

(1) Sugarcane Leafhopper :

Adult and nymph both suck up the sap from the lower surface of leaves and secrete honey which promotes a black fungal growth on leaves called sooty mould. The presence of this fungus on leaves

lower down the photosynthesis activity of the plant. In infested sugarcanes amount and quality of sugar both are decreased. 35% reduction in sugar is not uncommon. Cane juice from infested cane does not solidify properly. The peak period for infestation is September to November. Conducive factors are –

(i) High Humidity
(ii) Low temperature
(iii) Low rainfall or longer period of monsoon break

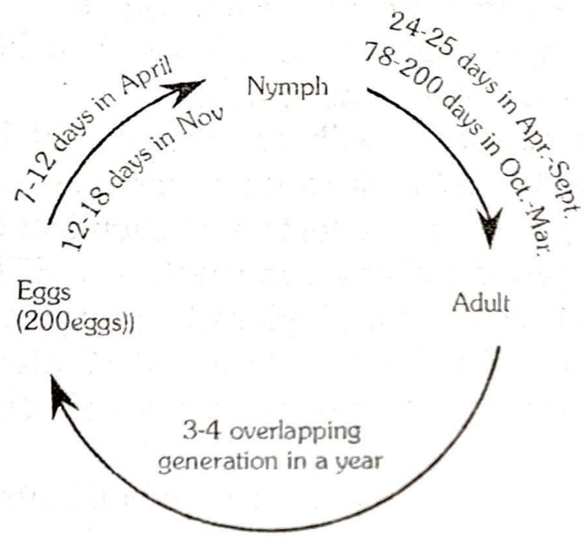

Fig.-9. Life Cycle of Sugarcane Leafhopper

(2) Sugarcane root borer :

The caterpillars enter from the base of the stem and move downwards towards root as a result the 'dead heart' formation takes place which does not give foul smell and can not be pulled out.

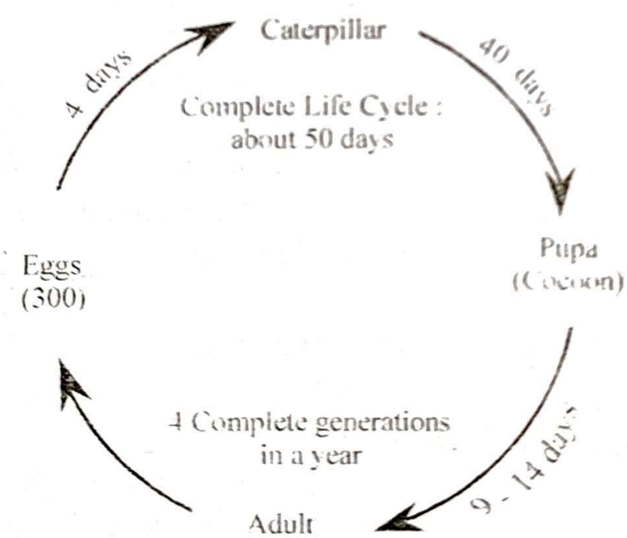

Fig.-10. Life Cycle of Sugarcane root boror

(3) Sugarcane shoot borer :

The larvae reach to the plant base and bore into the shoot and move upward forming dead heart which gives offensive odour.

(4) Sugarcane top borer :

The young larvae bore into the mid-rib of the leaves mining their ways to base from there they enter the spindle, feeding on growing point and soft portion of cane causing **bunchy top** and dead heart. The first two broods of this pest attack young plant before cane formation. In subsequent broods, the pest attacks the terminal portion of the Cane. Damage by third and fourth brood may result in more than 25% reduction in weight and decrease in quality of juice. The loss in sugar recovery is from 0.2 to 4.1 units.

(5) Gurdaspur borer :

The young larvae enter the top portion of the cane through a single hole just above a node. There, they feed gregariously by making spiral galleries which run upwards thus killing the plants. After about 7-10 days, when the cane top has dried up, the larvae come out and enter the adjoining canes single or in twos.

IPM in sugarcane :

For IPM in sugarcane pest monitoring, biological control and preventive control measures are necessary. Use of healthy seeds, clean cultivation/field sanitation and destruction of pests of early infestation are must for pest control. For the control of shootborer, stalk borer, mealybugs, scale insects and white flies, cultural practices, like selection of healthy setts for seed adjustment in planting time, detrashing, removal of late shoots and proper use of water and fertilizers minimize the number of insect pest. For primary infestation of gurdaspur borer and top borer mechanical control is helpful. Avoid use of cane setts from field infested more than 40% due to stalkborers or scales. Egg mass of white grubs and beetles and others can be picked up with hand.

For the control of top borer indigenous parasitic wasp (*Isotima javensis*) is released in the fields.This parasite is not effective in north India because pest and parasite both hibernate in winter but in South India the parasitic activity is seen through out the year because winter does not exist there. The parasite minimizes the number of pest upto 5 to 10%.

For the control of pyrilla, release cocoons of *Epiricania*

melanoluca 4000 to 5000/ha. For the control of shoot borer, internode borer, gurdaspur borer release Trichogramma 50,000/ ha/week. *Trichogramma chilonis* @100,000/ha in 2-3 batches. For scale insects coccinellied (predator) is effective. *Pharoscymnus horni* and *Chilocorus nigritus* may be released in the fields.

Insect-Pest of Pulses

S.N.	Common Name	Zoological Name	Family
1.	Pod borer	*Helicoverpa armigera*	Noctuidae
2.	Gram cutworm	*Agrotis ypsilon*	Noctuidae
3.	Tur Pod fly (Red gram Pod fly)	*Melanagromyza obtusa*	Agromyzidae
4.	Blue Butterfly (on Redgram)	*Lampides boeticus*	Lycaenidae
5.	The plume moth caterpillar *Tur means Arhar	*Exelastis atomosa*	Pterophoridae

(1) Pod borer :

It is a serious pest of chickpea, pigeonpea, pea, mungbean, urdbean, lentil, Soybean and cowpea. In America it is known as 'Cornworm' or cottonboll worm due to its serious damage to maize and cotton there. The young larvae feed on foliage for some time and later bore into the pods and feed on developing grains.

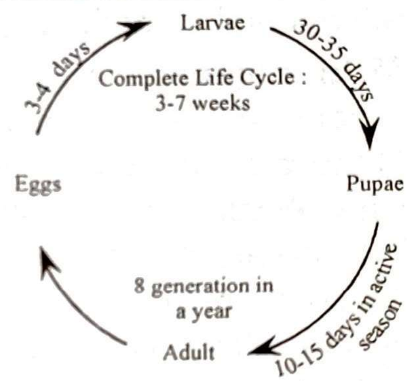

Fig.-11. Life Cycle of Pod borer

(2) Gram cutworm :

The caterpillars are responsible for damage. They cut the plants from the surface of soil at night (noctural in habits). In day time they hide in crack and crevices of fields.

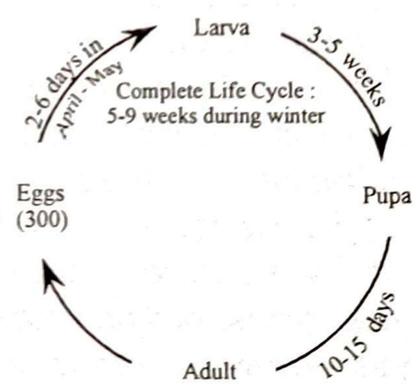

Fig.-12. Life Cycle of Gram Cutworm

IPM in Pulses :

Gram and redgram are main pulse crop grown in North India. The major pest of gram is gram caterpillar and pod borer and pod fly are the

major pest of redgram. For the control of these pests following IPM Schedule is suggested :

(i) Early maturing and early sown (before mid October) varieties are not affected because these mature before peak activity of the pest.

(ii) Crop rotation with non-host plants.

(iii) Use of resistant or tolerent varieties – Gram JG 315 and JG74 (middle India) ICCV-7 (South India) Arhar-Bahar and ICPL 332 (South India) and JA3 and JA4 (Middle India)

(iv) In North India intercropping of Gram + Linseed/ Mustard and in South India Gram + Coriander encourage natural enemies. Don't grow Arhar in the cotton growing areas. Intercropping of Gram + Barley/Wheat/Mustard/Linseed and Arhar + Jowar/Maize/ Bajra should be adopted.

(v) For Control of pod borer use bioinsecticide HaNPV @250-500 Larval equivalent (LE)/ha. The sraying should be done in evening time. Economic Threshhold level (ETL) for gram pod borer is one larva/5plants.

For control of this pest Neem Seed Kernel Extract 5%, Quinalphos, Endosulphan, Fenvelerate can also be used. For control of podfly spraying of monocrotphos is useful. After initiation of bud need based spraying at the interval of 15 to 20 days can be done.

(vi) Use of sex pheromone trap is also helpful in controlling podborers.

Insectpests of oil seeds

S.N.	Common Name	Zoological Name	Family	Remark
1.	White grub	*Holotrichia spp.*	Scarabacidae	Serious pest of ground nut.
2.	Mustard Aphid	*Lipaphis erysimi*	Aphididae	Serious pest of rape seeds
3.	Groundnut leaf miner	*Stromopteryx nertaria*	Gelechiidae	Pest of ground nut.
4.	Painted bug	*Bagrada cruciferarum*	Pentatomidae	Pest of Crucifers
5.	Mustard Sawfly	*Athalia proxima*	Tenthridimidae	Pest of

(1) White grub :

It is a root feeding pest. It feeds on functional roots of the plant leaving the original tap root. Some times it causes 100% damage. It is a soil inhabiting insect and prefers dry sandy/Sandy loam soils.

(2) Mustard Aphid :

All the stages of pest in gregarious form suck the sap from plant leaves, stems and branches, flowers and pods. It secretes honey dew on plants which promotes fungal growth, a black fungus called shooty mould. From Dec. to Jan. pest is very active. The females in plains multiply panthenogenetically. Females are viviparous. Winged and wingless both forms are present. Groundnut aphid (Aphid Craccivora) cause ***Rosette viral*** disease in groundnut.

(3) Mustard sawfly :

The Females have saw like ovipositors hence called sawfly. Larvae have 8 pairs of prolegs. The larvae feed in group of 3 to 6 on leaves during morning & evening and remain hidden during day time.

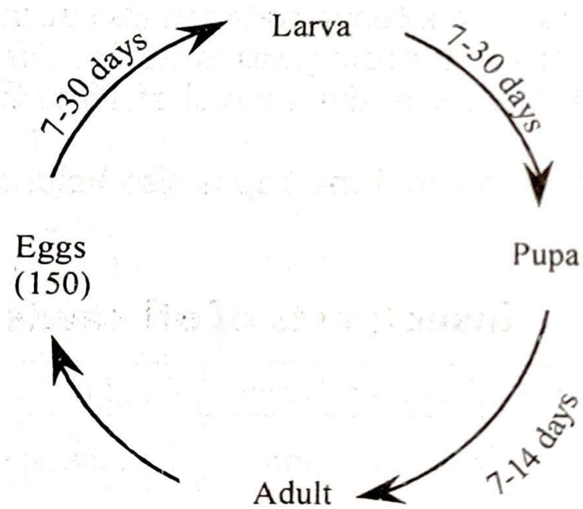

Fig.-13. Life Cycle of Mustard Sawfly

(4) Painted bug :

Adult + nymph both suck the sap from plants of family cruciferae.

IPM in Oils seed :

For the control of white grub both the stages adult beetle & grub should be controlled. In the early mansoon season the adult beetle can be controlled by spraying inseticides. At that time they live on Neem, Ber and Gular trees. The control of beetles in

comparison to grubs is cheaper and effective also. It should be done on co-operative basis. The seed can be treated with chlorpyriphos or Quinalphos @25ml/kg to prevent the damage of grubs. Fodder crops in summer may be sown in infested areas to attract grubs and plough in July/August to kill grubs. Beetles can be attracted by light traps. For the microbial control of grubs pathogenic bacteria, *Bacillus popillae* and pathogenic fungi *Matarrhizium anisoplinae, Beauveria brongniartii* and *B. brassiana* can be used for effective result.

Early sowing of mustard prevents aphid's attack.

For control of mustard aphid its natural enemies like predator, lady bird beetle and Aphidius (Parasite) may be encouraged. 50 to 60 aphids per 10 cm shoot length shows its ETL. At the time of minimum number of pollinators at morning and evening; the insecticide like monocrotophos can be used if necessary.

Insect Pests of Vegetables

(1) Fruit fly :

Dacus cucurbitae, Family Tephritidae order-Diptera

Food – Cucurbitaceous plants.

The females lay eggs in shoft fruits, a cavity is made by the sharp ovipositor and about a dozen white cylindrical eggs are laid, mostly in the evening time. The eggs hatch in 1-9 days and maggots bore into the pulp forming galleries. The attacked fruits decay because of secondary bacterial infection. After maturity the maggots drop down from fruits and pupate into the soil.

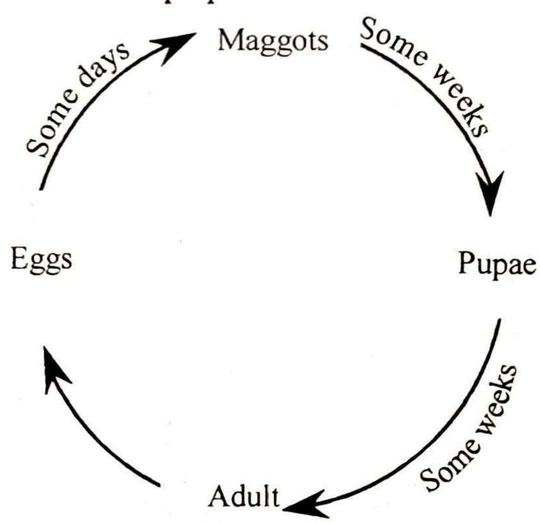

Fig.-14. Life Cycle of Furit Fly

(2) Red pumpkin beetle :

(Raphidopalpa sp) Fam. chrysomelidae (Coleoptera) Adult and grub both cause damage. The Grubs lead a subterranean life. Beetles are destructive to young plants, they injure the cotyledons, flowers and foliage by biting holes in them. Grubs bore the roots, underground stems and some time fruits touching the soil.

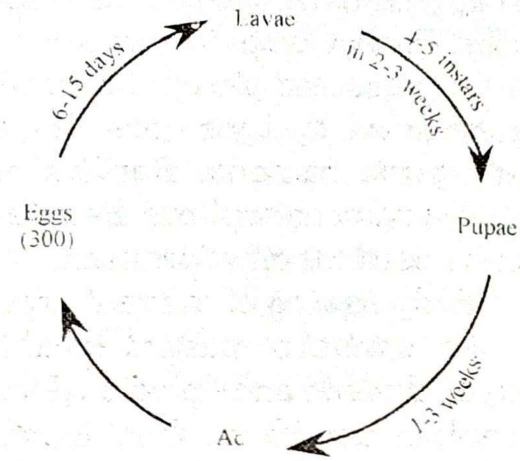

Fig.-15. Life Cycle of Red Pumpkin Beetle

(3) Brinjal borer :

Leucinodes orbonalis Family Pyralidae. The terminal shoot is attacked and the growing points are killed. They may bore flower buds and fruits also. The caterpillar may destroy 4-6 fruits.

(4) Hadda beetle :

Epilachna dodecastigme Fam. Coccinelidae. Adult and grub both are responsible for damage, they cause damage to plants of cucurbitaceae and solanaceae especially to Brinjal and tomato by feeding the upper surface of leaves. The pupae are found fixed with plant leaves, stem and base of the plant.

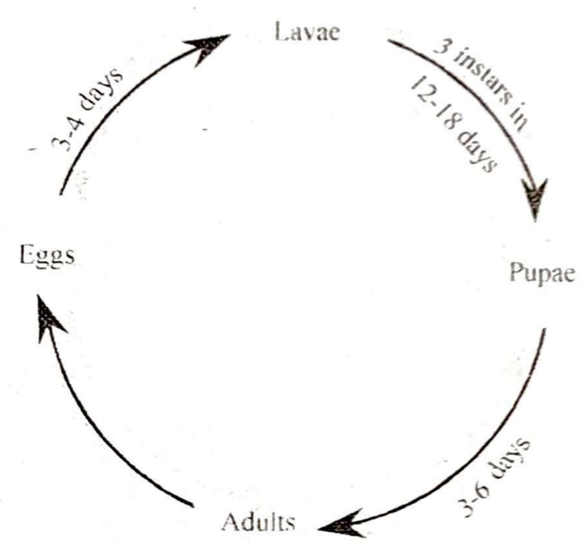

Fig.-16. Life Cycle of Epilachna Beetle

(5) Jassids (Leaf hoppers) :

Amrasca devastans Fam. Cicadellidae. It is popularly known as leaf hopper. It is a important pests of Potato and Lady's finger. They suck up the sap from plant leaves and tender parts. Both adult and nymph cause damage. They secrete a toxin which causes hopper burn in plants. Their legs are modified for hopping just like locusts or grasshoppers.

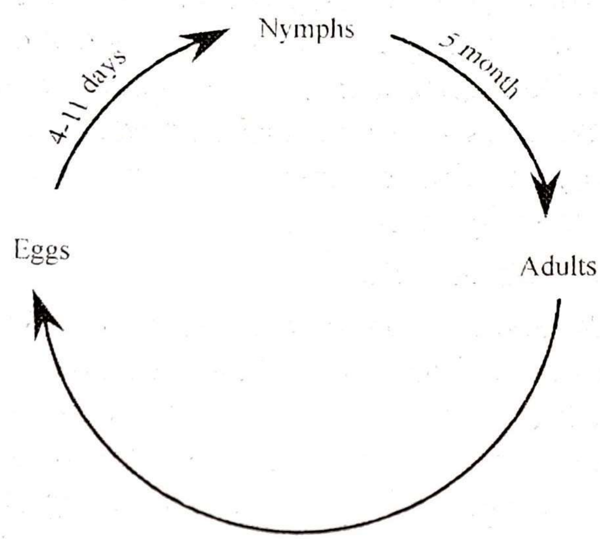

Fig.-17. Life Cycle of Jassids

(6) Tomato fruits borer. *Helicoverpa armigera :*

It is a major pest of tomato. For its control Marigold may be transplanted with tomato which attracts the natural enemies in large numbers. The ETL of this pest in tomato is 8 egg/15 plants. For the control of the pest *Trichogramma brasiliensis* can be used @ 50,000/ha at a interval of a week at least 6 times. Use of Ha-NPV @ 250LE/ha + 0.25% boric acid gives satisfactory result.

(7) Diamond-black moth – *Plutella xylstella* (Lepidoptera) : Fam. Ponomeutidae.

The caterpillars damage leaves of cabbage, cauliflower, rapeseed and mustard. This pest has become resistant to insecticides. Mustard is used as trap crop. About 80 to 90% pest are attracted to mustard. For control of this pest in cabbage Neem seed Kernal extract 4% can be sprayed at the head formation stage at the interval of 15 days twice or thrice.

(8) Mustard Aphid

(9) Painted bug

Insect Pests of fruits and Fruit trees

(1) Mango hopper :

Amritodus atkinsoni Fam. Cicadellidae. It is a major pest of mango. Adult and nymph both suck the sap from leaves, inflorescence and tender shoots. They also secrete honey dew which causes the development of black fungus sooty mould. For the control of the pest, spraying of Cypermethrin (500 ppm), Carbaryl (0.1%) or Neem seed Kernal extract 4% can be done at the time of fruit setting. Parasites *Aprotocetus* sp, *Ganatocerus* sp. *Polynema* Sp. and predators *Cryspa, Lacciperda, Maidada nominensis* are identified as bioagents. Proper spacing of 10m x 10m and pruning is helpful in pest management.

(2) Fruit fly : *Dacus dorsalis*

It is a major pest of mango and guava. The female deposits eggs inside the fruit 3 to 4 mm deep. After hatching of eggs maggots start feeding on the pulp as a result fruits decay and ultimately drop down. The population of the pest reaches at peak in March-April, May-June and September-October. Spraying of Deltamethrin 0.0025% and then Fenthion 0.05%, Dimethoate 0.04% or Carbaryl 0.1% at the interval of 12 to 15 days is recommended for mango. For guava 0.03% Phosphamidon can be used. Poison baiting is also helpful for controlling the pest.

(3) Mealybug : *Drosicha mangiferae* Fam. Margarodidae (on mango)
Dysmicoccus brevipes (on pineapple)
Maconcellicoccus hirsutus (on grape)

Host - All Common fruits.

Damaging stage – Nymph + Female adult only by sucking. For control of mango mealy bug, digging of soil around the tree and mixing of 5% Malathion dust is beneficial. Use of greese band and cellophone band on the trees is also effective. Spraying of 0.03% Monocrotophos can be done if other methods fail. For control of pineapple mealy bug, use phorate @1.75kg/ha. For grape mealy bug, use of Dichlorvos is effective. A predator Lady bird beetle predator Australian Origin *(Cryptolaemus montrouzievi)* @ 1200 beetles/ha can be used for effective check of the pest.

(4) Fruit sucking moth :

Otheis fullonica, Ophideres materna (Lepidoptera: Noctuidae) Damage : Only by Adult (not larvae). These pests are minor pest of citrus, mango, grapes and apple. The adult moths cause damage. They pierce the fruits and make punctures for sucking juice. The site of attack is infected by fungus and bacteria with the result whole fruit turns yellow and drops off the tree.

Managements : Destruction of alternate host plants from vicinity.
Disposal of fallen fruits which attract pest.
In small scale bagging of fruits can be done.

Poison baiting – gur 1 kg + Vinegar 60g + lead arsenate 60g + water 10 litres. This solution should be applied in a wide mouth bottle 1 bottle per 10 trees. Bottle containing bait should be tied to the trees.

(5) Citrus Psylla :

Diaphorina citri Fam. Psyllidae : It spreads greening disease (Gracillicutes gram negative bacteria). It is serious in Punjab. The main cause of damage are nymphs & adults which crowd on terminal shoots and buds and suck plant sap. Leaves curl up and drop and shoot may even die.

Control: Infested plants may be sprayed with dimethoate (1ml/ litre of water) or phosphomidon (1ml/2 litre of water) or demeton (1ml/litre of water)

Natural enemies : *Coccinella septempunctata L.*
Chrysopa sp.
Chilomenes sexmaculata.

(6) Lemon butterfly : *Papilio demdeus* – Lepidoptera : Papilionidae

The caterpillars are responsible for damage. They cause severe defoliation by eating. The damage is very severe to young plants, they may become completely devoid of leaves and ultimately die. The peak period for infestation is April to May and August to October.

Control : 1. Hand picking of caterpillars on smaller plants and their destruction.
2. Spraying of quinalphos (1ml./litre of water) or fenvralerate, cypermethrin or decamethrin @ 0.2 to .3ml/litre of water)

Natural enemies – *Trichogramma evanescens* (egg parasite)
Erycia nymphalidaephaga (Parasite of caterpillars)

(7) Anar butterfly – (Pomegranate fruit borer)

Lepidoptera : Lycaenidae; *Virochola isocrates*

Pomegranate, guava, Ber, loquat, Sapota and tamarind are attacked but most destructive to pomegranate.

The caterpillars cause damage. They bore into fruits and feed on seeds. They plug the entry holes by their anal ends. The infested fruits drops prematurely or when the mature fruits are opened seeds are found eaten up.

Control : Bagging of fruits with cloth bags, butter paper or polythene on small scale is very effective.
Spraying of phosphomidon (3ml/10 litres of water) at interval of 15 days at least 5 times is recommended.

(8) San Jose Scale :

Quadraspidiotus perniciosus Hemiptera : Diaspididae

Plants beloning to the family Rosaceae such as apple, plum, pear, peach are severely attacked, though it is serious pest in temperate regions on nearly 700 different species of fruits.

Damage is caused by nymphs and female scales which suck up the sap from twigs, branches and fruits though all parts above the ground are attacked. Large number of insects may cause death of the plant.

Management –
1. Orchard sanitation. Infested pruned material should be burnt.
2. The plants in nursery can be protected by applying Carbofuran granules @0.75 – 1.0 g a.i. per plant.
3. 2% miscible oil can be sprayed during Feb. and March.
4. Use of natural predators like *Aphytis procila,Chilocorus bijugus, Coccinella septempunctata* is beneficial

9. Woolly aphid : *(Eriosoma lanigerum)*

Hemiptera : Aphididae

It is a serious pest of apple, pear and crab-apple. Infested plants have pale green leaves and whitish cottony patches on stem and branches. The characterstic galls or knots are formed on roots and other underground parts.

Management :

1. Use of resistant root stock like Golden Delicious Morton stocks 778, 779, 789 and 793 and Mailling Merton (MM) root stocks like MM 106, MM 109, MM 111.
2. A parasite *Aphelinus mali*, very effectively controls the pest.
3. Spraying of 0.05% Chlorpyriphos or fenitrothion.
4. Use of phorate or Carbofuran granules in soil.

10. Apple root borer :

Dorystenes hungelii Coleoptera : Cerambycidae

The grubs are responsible for damage. They bore the roots of apple. A number of other fruits like Cherry, peach, pear, walnut are attacked. The eggs are laid 8-12 mm below the soil. The emerged grubs go 100 to 250mm down into the soil and feed on organic matter and roots of the plant. As a result of their feeding young plants die and older become weak and can not tolerate strong wind. Sandy soil are suitable for pest. Management

1. Avoid sandy soils for planting.
2. Inter-culture under the tree helps in killing grubs
3. If infestation has occurred, treat the soil with phorate granule @100g. a.i/tree. Chlorpyriphos may also be used for soil treatment.

*

17 Plant Pathology : An Introduction

The term Plant pathology or Phyto-pathology has been derived from three greek words.

Phytopathology = Phyton + Pathos + logus
↓ ↓ ↓
Plant Ailments Knowledge

Disease is a malfunctioning alteration of one or more ordered processes of energy utilization in a living system, caused by the continued irritation of a primary factor or factors.

Ancient Indian writer Surapal gave a detailed account on plant diseases in his book Vraksha Ayurveda. In this book he has classified plant diseases into External and Internal diseases. Theophrastus, the ancient Greek Philosopher in his book "Enquiry into plants" had included some of his observations regarding plant diseases.

Dutch worker *Leeuwenhock* invented the microscope in 1675 and through it observed and described bacteria in 1683. this lead to the beginning of a new era in Biology. Italian botanist Micheli (1729) was the first to study fungi and observe fungal spores. A research paper on Bunt or Stinking smut of wheat was published by French botanist Tillet in 1755. In his paper Tillet proved that wheat seeds with black powdery mass on their surface had greater potential to cause diseases than healthy seeds. Thus it was concluded that Bunt was an infectious disease having some relationship with fungi. Prevost in 1807 proved that wheat bunt disease was caused by a fungus. He also discovered the life-cycle of the Bunt fungus. In 1853 Anton de Bary (1831-1888) confirmed the findings of Prevost. De Bary through his extensive studies on the late blight disease of potato conclusively proved that microorganism play an important role in plant diseases. Besides this De Barry also discovered the heteroecious nature of the rust fungus. He also described the life-cycle of Downey mildew fungus and provided informations about the role of enzymes in host-

pathogen relationships. Because of his great contributions *De Bary* was given the title ***"Father of mycology."*** Julius Koon in 1858 wrote the first book on plant pathology in which he provided valuable informations regarding the role of fungi in plant disease development. ***Julius Koon*** is therefore called the ***Father of Modern Plant Pathology.***

German scientist Brefeld, who was a co-worker of De Bary, developed techniques of Artificial culture of microorganisms in between 1875 and 1912. These techniques made the study of infectious microorganisms easier.

In the latter half of Nineteenth century France had extensive cultivation of grapes for manufacturing wine. Downey mildew of grapes was introduced into Europe from America in 1878. ***Prof. Millardet*** of France discovered ***Bordeaux mixture*** for the control of this disease. At that time *Bordeaux mixture* was successfully used to control late blight of Potato and downey mildew disease of Grapes.

In 1876 Louis Pasteur and Robert Koch reported that Anthrax disease in Cattle was caused by a bacterium. American scientist Prof. T.J. Burill (1878) discovered that Fire blight disease in apple and pear was of bacterial origin. His fellow American scientist E.F. Smith till the end of 1895 had conclusively proved the importance of bacteria as plant pathogens.

Swedish scientist ***Erikson*** in 1894 reported about of the existence of ***Physiological races*** in Rust fungus.

Ward (1903) and Salmon (1903, 1904) discover Physiological specialization in Cereal rust and powdery mildew. According to E.C. Stakman of U.S.A. due to continuous evolution of races & biotypes of the rust fungus their pathogenic capacity also keeps changing and so does the resistance capacity of the host.

Blakeslee in 1904 discovered ***Heterothallism in fungi*** and informed that in the life-cycle of fungus dissimilar nuclei participate. Heterokaryosis i.e. coming-together of dissimilar nuclei in a single fungal cell was discovered by Burgeff (1912 & 1914). Hansen and Smith for the first time demonstrated about the development of physiological races as a result of heterokaryosis. Flor (1955) proposed the Gene to gene hypothesis to explain disease

resistance and susceptibility.

Needham in 1743 reported plant parasitic nematodes in wheat gall. In 1875 Berkebey and Schacht discovered the root knot nematode and cyst nematode of beet.

Cobb (1913-1932) studied the structure of many plant parasitic nematodes and classified them.

Adolf Meyer for the first time in 1836 discovered the viral disease tobacco mosaic. He proved that sap derived from diseased plant leaves has the potential to cause infection in healthy plants.

F.F. Smith in 1891 through his studies on Peach yellow disease concluded that it was an infectious disease whose transmission from diseased to healthy plants occurs through Grafting and Budding. Ivanowski in 1892 found that the agent causing tobacco mosaic could not be filtered through a chamberland filter although bacteria got easily filtered through it. Thus viruses were found to be smaller than bacteria.

Beijernick in 1898 proved that tobacco mosaic disease was not caused by a microorganism rather it originated from *Contagium Vivum fluidum* which he later called ***VIRUS***. In 1935 *Stanley* treated the sap obtained from Tobacco mosaic virus infected leaves with $(NH_4)_2 SO_4$ and obtained crystalline protein. For this he was awarded Nobel Prize. Bowden & Pirie in 1936 proved that the crystalline powder of Bushy stunt virus of tomato contained Protein and nucleic acid. After the invention of ***Electron microscope*** by ***Knoll & Ruska*** (1932), *Kanschietal* in 1939 using this microscope studied the shape and size of the virus particle. Geirer and Schramm in 1956 proved that nucleic acid of the virus particle was the actual disease inciting agent. Viroid is only a naked nuclic acid molecule. The term 'viroid' was by T.O. Diener. Viroid is devoid of any protein coat and its RNA has a high molecular weight.

Potato Spindle tuber was the first disease reported to have been caused *by a* ***viroid.***

Virus = Nucleic acid (DNA or RNA) + Protein (outer cover)

Lipo-virus = Nucleic acid + Protein + lipid (e.g. Influenza virus)

Animal virus = DNA + Protein (or Bacteriophage)

Plant Virus = RNA + Protein
Viroid = nucleic acid only
Plant viroid = RNA only
DNA = Deoxyribose nucleic acid
RNA = Ribose nucleic acid

Plasmid/Episome : Extrachromosomal fragments found in bacterial cells.

Virus, viroid and plasmids all contain nucleic acid and lack their own metabolic potential.

Japanese scientist Doi et al in 1967 explained that diseases like witches broom of Potato, mulberry dwarf and Aester yellows etc. which were earlier thought to be of viral origin were actually caused by MLOs (Mycoplasma-like Organisms). Mycoplasma are larger than viruses but smaller than bacteria. They are devoid of Cell wall and cytoplasm is enveloped by a lipo-protein plasma-membrane. It is highly resistant against the antibiotic Penicillin but is sensitive to Tetracyclin antibiotic. ***Tetracyclin*** is therefore used to control mycoplasma. Mycoplasma was first isolated from sheep infected by Pleuro-pneumonia and therefore called PPLO (Pleuro-pneumonia like organisms). Most of the yellow diseases of plants are caused by Mycoplasma.

K.R. Kirtikar was pioneer worker on plant pathology in India. Kirtikar was the first Indian scientist who collected many Fungi and identified them. ***E.J. Butler*** of Imperial Research Institute, Pusa (Bihar) before 1910, did detailed studies of Fungi and diseases caused by them. He wrote a book *"Fungi and Diseases in Plants"*. He is therefore called the ***Father of Modern Plant Pathology*** *in India*. J.F. Dastur (1886-1971) was the first Indian plant pathologist to study in detail on fungi and plant diseases. B.B. Mundkur developed resistant varieties to control cotton wilt disease. The credit for identifying and classifying the smut fungi found in India also goes to Mundkur. He established the Indian Phytopathological institute and started the publication of Indian Phytopathology in 1948. ***Dr. Karam Chand Mehta*** *(K.C. Mehta)* of Agra College discovered *diseases cycle* of cereal rust in India. ***Prof. Jaichand Luthra and Sattar*** developed *Solar treatment* technique of seeds to control *loose smut* disease in wheat. *M.J.*

Thirumalachar performed extensive studies on rusts and smuts in India. Thirumalachar on joining 'Hindustan Antibiotics' developed antibiotics like Oreofungin and Streptocyclin which lead to their successful use in plant-disease control in later years.

Technical terms : An Introduction

1. **Blight** : A non-restricted tissue disintegrating symptom characterized by general and rapid killing of leaves, flowers & stem.

2. **Hyperplasia** : Excessive development due to increase in the number of cells.

3. **Hypertrophy** : Excessive growth due to increase in size of cells.

4. **Hypersenstivity** : Excessive sensitivity of plant tissues to certain pathogens. Affected cells are killed quickly, blocking the advance of obligate parasites.

5. **Parthenogenesis** : Formation of embryo without fertilization.

6. **Rogueing** : Removing of unwanted (virus infected) plants from a field of crop.

7. **Obligate parasite** : A parasite that in nature can grow and multiply only on living organisms.

8. **Facultative parasite** : An organism that is usually saprophyte under certain conditions may become parasite.

9. **Facultative saprophyte** : An organism that is usually parasite but may also live as a saprophyte.

10. **Damping off** : Destruction of seedling near the soil surface, resulting in the falling of seedling on the ground.

11. **Mildew** : A plant disease caused by a fungus in which the mycelium and spores are seen as a whitish growth on the host surface.

12. **Virulent** : Strongly pathogenic

13. **Incubation period** : Period between infection and appearance of symptoms induced by parasitic organisms.

14. **Ination** : Deformity caused by viral infection.

15. **Eradication** : Control of plant diseases by eliminating the plants that carry the pathogen.

16. Necrosis : The death of cells or of tissues.

17. Alternate host : One of the two kinds of plants on which a parasitic fungus (e.g. black rust of wheat caused by *Puccinia graminis tritici*) must develop to complete life-cycle.

18. Autaceious fungus : A parasitic fungus which completes its entire life cycle on the same host (e.g. *Melampara lini*)

19. Agar : A gelatin-like substance obtained from sea weed (red algae *Gracilaria, Gelidium* etc.) and used to prepare culture media on which microorganisms are grown for study.

20.Smut : A disease caused by Ustilaginaceae : characterized by masses of dark, powdery spores.

21.Sooty mould : The sooty envelope formed by the fungal mycelia on the surface of leaves and fruits.

22. Witche's broom : Broom like growth.

23. Mycorrhiza : Symbiotic relationship between roots of higher plants and fungal mycelia which is essential for the growth of these plants.

24. Fungistatic : A compound which prevents fungal growth without killing the fungus.

25. Rust : A disease of grasses and other plants giving a rusty appearance to the plant and caused by uredinales (rust fungi).

26. Canker : A necrotic or sunken lesion on a stem, branch or fruit of a plant (e.g. citrus canker caused by *Xanthomonas citri*)

27. Plasmogamy : Fusion of cytoplasms of two cells.

28. Physiologic race : One of a group of microorganisms like in morphology but unlike in certain cultural, physiological, pathological or other characters.

29. Physiological specialization : the existence of a number of physiologic races or forms within a species or a pathogen.

30. Latent virus : A virus that does not induce symptoms in its host.

31. Latent infection : The stage in which a host is infected with a pathogen but does not show any symptoms.

32. Gummosis : Production of gum by plant tissue.

33. Masked symptoms : Virus induced symptoms which are not visible under certain environment conditions but get to be expressed under certain conditions of temperature and pressure.

34. Spot : Disease symptom in which certain restricted tissue disintegrating areas are produced on leaves, stem and fruit.

35. Haustorium : A projection of hyphae into host cells which acts as a penetration and absorbing organ.

36. Biotype : A subgroup within a species usually characterized by the possession of a single or a few characters in common.

37. Toxin : A compound produced by a microorganism and being toxic to a plant or animal.

38. Bacteriostatic : A chemical or physical agent that prevents multiplication of bacteria without killing them.

39. Bacteriophage : A virus which infects specific bacteria and kills them.

40. Scorch : Burning of leaf margins as a result of infection or unfavourable environmental conditions.

41. Blotch : A disease characterized by large and irregular spot or lesions on leaves, shoots and stems.

42. Exudate : Liquid discharge from plant tissue.

43. Heterotrophic : An organism depending on an outside source for organic nutrients.

44. Host : A plant that is invaded by a parasite and from which the parasite obtains its nutrients.

45. Etiolation : yellowing of the plant due to deficiency of light.

46. Scab : A rough, crust like diseased area on the surface of a plant organ. A disease in which such areas are formed.

47. Gall : A swelling produced on a plant as a result of infection by certain pathogens.

48. Yellows : Yellowing and stunting of host plant.

49. Antigen : A substance (usually a protein, lipid or carbohydrate) which after entering into a body activates the production of antibody.

50. Antibiosis : the phenomenon in which a substance produced by one microorganism is harmful to another organism.

51. Antibody : A protein produced by specific stimulation when a foreign antigen enters into the blood of an organism. Antibodies get attached with the antigens and makes them ineffective or harmless.

52.Race : A genetically distinct mating group within a species; also a group of pathogens with distinct pathological or physiological characterstics.

53. Phytoalexin : A substance that inhibits the development of a fungus on hypersensitive tissue, formed only when host plant cells come in contact with the parasite.

54. Foliocellosis/Frenching : A disease caused due to deficiency of Zn in fruit trees (specially belonging to *citrus* family) in which new leaves develop inter-veinal chlorosis, get reduced in size and branches are also not properly developed. The plant has a bushy appearance and the branches show die-back symptoms. It is also called **leaf mottle disease**.

55. Exclusion : control of plant disease by excluding the pathogen or infected plant material from disease free areas.

56. Pleomorphism/polymorphism : Having various forms in a life cycle – The rust fungus is allomorphic as it produces five different types of spores in its life-cycle.

57. Hetoroecious fungus : Passing different stages of life history in different hosts.

58. Epidemic disease : A wide spread & severe outbreak of a disease.

59. Rhizoids : A short, thin hypha produced by a thallus that grows towards the substrate.

60. Saprophyte : In organism which lives on dead and decaying organic matter.

61. Downey mildew : A plant disease in which the mycelium & spores of the fungus appear as a downey growth on the host surface.

62. Mosaic : Symptom of certain viral diseases of plants characterized by intermingled patches of normal and light green or

yellowish colour.

63. Wilt : Loss of rigidity and dropping of plant parts wholly or partially.

64. Rugose : Rough and crinkled leaves produced as a result of viral infection e.g. Rugose mosaic of Potato.

65. Russetting : Brownish roughened areas on fruit skin produced as a result of excessive cork formation.

66. Rickettsia like Organisms : RLOs a prokaryotic microorganism having a cell wall and obligate intra-cellular parasite.

67. Susceptibility : The inability of a plant to resist the effect of a pathogen.

68. Susceptible : A plant or species which is incapable of resisting the effect of a pathogen.

69. Pathogen : An disease causing agent in plant.

70. Resistance : The ability of an organism to overcome, completely or partially the effect of a pathogen.

71. Vector : An insect able to transmit a pathogen.

72. Disinfectant : A physical or chemical agent that frees a plant or organ from infection.

73. Immunity : The state of being exempted from infection by a given pathogen.

74. Ring spot : A circular chlorotic area with a green centre; symptom of many viral diseases.

75. Virion : A complete virus particle.

76. Viroid : A naked nuclueic acid which resembles virus but is devoid of protein coat.

77. Carrier : A plant or an organism which carries an infections agent but does not show symptoms of disease produced by the agent.

78. Lesion : A localized area of discoloured, diseased tissue.

79. Rot : The softening, discolouration and disintegration of a succulent plant tissue as a result of fungal or bacterial infection.

80. Disinfestant : An agent that kills or inactivates pathogens in the environment or on the surface of the plant, prior to infection.

81. Antagonistic symbiosis : Parasitic symbiosis in which one organism benefits from another.

82. Endemic disease : A disease which regularly occurs on a particular area of earth or country.

83. Shot hole : A symptom in which small diseased fragments of leaves fall off and leave small holes in their place.

84. Heterothallic fungi : Fungi producing compatible male and female gametes on the physiologically different mycelia.

85. Vein clearing : Distruction of chlorophyll in the vein tissue, as a result of infection by a virus or other pathogen.

86. Vein banding : Bands of green tissue along the veins while the tissue between the veins become chlorotic.

87. Die back : Progressive death of shoots and roots generally starting at the tip.

88. Anthracnose : A leaf spot or fruit spot type of disease caused by fungi that produce their sexual spores in an acervulus.

89. Infection : Establishment of the pathogen in the host.

90. Infections disease : A disease caused by a pathogen which can spread from a diseased to a healthy plant.

91. Quarantine : Control of export and import of plant to prevent spread of diseases or pests.

92. Syndrome : A set of symptoms which charactersize a disease.

93. Transmission : Transfer of pathogen such as viruses from one plant to other.

94. Conjugation : A type of sexual reproduction in which morphologically similar gametes fuse.

95. Culture : Growing microorganisms on a prepared nutrient medium.

96. Homothallic fungus : Fungi producing compatible male and female gametes on the same mycelium.

97. Pustule : Small blister like elevation of epidermis.

98. Chlorosis : Yellowing of green tissue due to chlorophyll destruction.

Rust in India

In our country, out of the major two rusts infesting crop, wheat, leaf rust and stripe rust, the former is more harmful. The three types of host related with this disease are as follows :

(i) Alternate host : This host is required to complete the life-cycle e.g. *Barberis* is the alternate host of stem rust whereas *Thalictrum* is the alternate host of leaf rust. In India however alternate hosts have no importance in the life-cycle of rust fungus. Yellow rust has no alternate host in India.

(ii) Collateral host : Besides agricultural crops the uredial and conidial stages of the rust pathogen surviv on Grass hosts e.g. Bromus sp and Agropyron are the collateral host of yellow rust. Brome grasses serve as collateral host for leaf rust and sim. arly *Bromus* sp (In Northern India) and Brija minor (in Southern India) are collateral hosts for Black rust.

(iii) Primary host : The host on which the rust pathogen produces its telial & resting stages is the Primary host. Dr. K.C. Mehta and his team have identified three hosts on which uredial spores are produced.

(a) Continued available host

(b) Self growing wheat plants.

(c) Grass host e.g. Bromus etc.

Mehta and his associates undertook research surveys from the foothills to the higher attitudes of Himalayas and concluded that Rust fungus perpetuates in hills of Northern India. L.M. Joshi, a student of Dr. Mehta reported that although the rust pathogen perpetuates in Northern India but its main source was the coastal areas of Indian Ocean and Bay of Bengal.

According to Dr. K.C. Mehta wheat crop occupies maximum time of the year in hilly areas of Sindh. The short period of 2-3 months when the wheat crop is not available in the fields, the pathogen survives through its uredial stages on wild wheat and other grassy hosts.

Predisposing factors

(a) Nearness of hills.

(b) Speed and direction of wind

(c) Amount of moisture and sunlight

(d) Suitable hosts.

There are four stages in the life cycle of rust organism. These have been represented by roman digits in the given table. The functions of these four stages had been well understood before 1927.

StagesName	Remarks	
I II III IV	Aecial Uredial Telial Basidial	Functions already Understood.
O	Pycnial	Number 'O' has been assigned to this stages as the function of this stage was not known before 1927.

Craigie in 1927 discovered the function of Pycnial stage and reported that plasmogamy occurs in this stage. Craigic for the first time reported Heterothallism in Rust fungus. Among these five stages only uredial (II) and telial (III) are found on wheat. Pycnial (O) and Aecial (I) stages are present on Berberis and Mahonia whereas Besidial stage is produced on the inactive substratum on which teleutospores are produced.

Physiological Specialization :

Erikson (1893) reported that *Puccinia graminis* was not a composite pathogen. He classified it into five formae specialis or varieties. These varieties differed from each other with respect to the shape of uredospore and other morphological characters such as colour and roughness. The term f. sp. has been placed between gaminis and tritici which indicates that triticum is a special form of Triticum allies. This very property of the organism is called Physiological specialization.

Later Stakman (1915) reported that even *puccinia graminis* f. sp. tritici was not a composite organism. He concluded that the special form of *Puccinia graminis tritici* was again made up of several forms which he called 'Biotypes'. He again observed that even a Biotype was not a composite organism and was composed of several 'races'.

Biotypes – represented by Arabic numerals i.e. 1, 2, 3, 4

Races – represented by roman letter a, b, c, d,

Example : the complete name of fungus causing Black rust/ stem rust is as follows :

Puccinia graminis f. sp. *tritici* 16d.

18 Chemicals used in Disease Control

Certain chemicals are toxic to pathogen. Such chemicals check the growth and development of pathogens and kill them. Based on the nature of the pathogen against which these chemicals are used, the latter have been classified into fungicides, bactericides, nematicides, viricides etc.

Fungicides :

Fungicide = Fungus + caedo = Latin words

Fungus ↓ Means ↓ Fungus

caedo ↓ Means ↓ to kill

Chemical or physical agents (Heat, UV rays etc.) having the potential to kill fungal pathogen come under this category. Although the term fungicide is generally used for chemical agents only.

Certain chemicals temporarily check the growth of fungal pathogen and do not kill them. Such chemicals are called **fungistatic** chemicals. Chemicals which check the production of spores in fungi are called antisporulant although all such chemicals which protect the plants from fungal pathogen come under the broader definition of fungicide.

Types of Fungicides :

(A) Sulphur fungicides : Sulphur since ancient times has been used as a fungicide. e.g. – Elemental Suphur and lime sulphur

(B) Copper Compound fungicides : The fungicidal nature of bone stone, copper sulphate was first of all discovered by **Prevost** (1807) against Bunt disease.

(B_1) Bordeaux Mixture : Prof. ***Millardet*** of France in 1882 accidentally discovered Bordeaux mixture from the mixture

of copper sulphate and lime. This he successfully used to control downey mildew of grape. Millardet first of all prepared Bordeaux mixture by mixing copper sulphate, lime and water in the ratio 8:15:100 (8kg of $CuSO_4$ + 15 kg lime + 100 litre water). But this mixture was extremely powerful and caused foliar injury. Bordeaux mixture is now prepared in following concentrations :

(a) 4 : 4 : 50 = 0.8% (4 pounds copper sulphate + 4 Pounds lime + 50 gallon water)

(b) 5 : 5 : 50 = 1.0% (5 pounds copper sulphate + 5 pounds lime + 50 gallon water)

Nowadays 5:5:50 (1.0%) ratio is often used.

Thus Bordeaux mixture contains three ingredients :

(i) Copper sulphate/Blue stone = $CuSO_4 \cdot 5H_2O$

(ii) Quick lime

(iii) Water

The following reactions take place in Bordeaux mixture

$$CuSO_4.\ 5H_2O + CaO \rightarrow Cu\ (OH)_2 + CaSO_4$$

Because of the lime content High volume spray is used for the application of Bordeaux mixture.

(B_2) Burgundy mixture/Soda-Bordeaux mixture : In this mixture lime is replaced by sodium carborate or washing soda or soda ash, the rest composition being similar to Bordeaux mixture. In ancient Europe because of the non-availability of Quick lime Mason in 1887 used Sodium carbonate in its place. This he did in the city of Burgundy and therefore the name Burgundy mixture.

Burgundy mixture = Copper Sulphate + Sodium Carbonate + Water

Burgundy mixture =	Copper Sulphate +	Sodium Carbonate +	Water
	↓	↓	↓
	5 or 6 lb	$6\frac{1}{4}$ or $12\frac{1}{2}$ lb	50 gallon
	↓	↓	↓
	$CuSO_4\ 5H_2O$	Na_2CO_3	H_2O

(B_3) Chestnut compound/Cuprammonium fungicide :

Use of chestnut compound as a fungicide was first of all done by Bewlery in 1921 against Damping off disease of seedlings.

Chestnut Compound or Cuprammomium Fungicide	=	two parts by weight of crystalline $CuSO_4$	+	11 parts by weight of $(NH_4)_2\ CO_3$

(B_4) Chaubattia Paste : This was first of all used at the Government Fruit Research Centre, Almora. This was used as a wound dressing fungicide against diseases of apple and pear such as Black stem, brown stem etc.

Chaubattia Paste	=	Copper Carbonate	+	Red lead	+	Lanolin/raw
		800g $CuCO_3$		800g		linseed oil 1000 ml.

(C) Thiocarbamate Fungicides : The importance of Thiocarbamate in the field of Fungicides is comparable to the discovery of DDT as an insecticide. Though ***Spergon*** was the first Organic fungicide to be used commercially. In 1931 ***Tisdale*** first observed about the possible use of Thiocarbamate as a Fungicide. Thiocarbamate has been grouped into three categories :

(C_1) Thiuram disulphides : Among its different compounds only tertramethyl thiuram disulphide is used as a fungicide. This product is called ***Thiuram/thiram.*** It was included in the list of fungicides in 1934 basically as a ***seed protectant***. But later on it was started using as a ***Foliage protectant*** and in certain conditions for ***soil treatment*** also. Its general formulation for its use as spray is 80% W.P. and 50% colloidal suspension. For seed treatment usually 50% powder is used. For better results 250 g.a.i. of Thiram is dissolved in 100 litre water and the seeds are soaked in it. For soil treatment 10-15 kg a.i. is used.

(C_2) Metallic dithiocarbamates :

(i) Ferbam : It is a *Fe (Iron)* containing fungicide.

It was developed by Tisdale and Williams in 1931. Its commercial use as a fungicide started in 1943. In temperate countries it is used against disease of apple and other fruits. For spray its formulation is 0.2 – 0.3% a.i. Its effect decreases on mixing with copper, lime and mercury.

(ii) Ziram : It is a ***Zinc*** containing fungicide. This is the most stable among the group of Dithio-carbamate fungicides. It has been found to be an effective fungicide to control diseases caused by Fungi Imperfecti in fruits and vegetables and also early blight of potato. It provides additional advantage in soil deficient in Zn. For spray purpose formulations of 0.2 – 0.3%

a.i. and 50% W.P. are available in market.

(C_3) Ethylene bisdithiocarbamates :

(i) Nabam : Nabam is a sodium containing fungicide. Because of its phytotoxicity and instability it is not usually used in fields. Although it gives better results on mixing with $ZnSO_4$ and lime.

(ii) Zineb : It is a ***Zn***-containing fungicide. Except certain sensitive plants Zn is usually not harmful for crops. It is used to control many diseases in plants. It is used for ***soil treatment*** to control Damping off and other soil-borne diseases. It has nematicidal property and is used to control *Meliodogyne spp.*

(iii) Maneb : This fungicide is similar to Zineb but in Maneb Zn is replaced by ***Mn*** i.e. it is *Mn-containing* fungicide. It was included in the list of fungicides in 1950. It is very effective against Foliar diseases especially Blight diseases of potato and tomato.

(iv) Mancozeb : It contains both Zn and Mn.

(v) Vapam/Metham-sodium : It is a ***soil Fumigant*** which was enlisted in 1954. It is used in partial sterilization of soil for the control of *Soil Fungi* and *nematodes*. It also acts as a herbicide.

S (Sulphur) is an important component in the structural formula of thiocarbamate fungicide.

S.No.	Fungicides	Metal constituent	Remark
1.	Thiuram/Thiram	No metal	used for Seed treatment+Soil treatment Foliage Protectant
2.	Ferbam	Fe	Used for Spraying
3.	Ziram	Zn	Used for Spraying
4.	Nabam	Na	–
5.	Zineb	Zn	Soil treatment+Nematicide
6.	Maneb	Mn	Effective for foliar disease control
7.	Mancozeb	Zn + Mn	Effective for foliar disease control
8.	Vapam	Na	Soil Fumigant + Herbicide

(D) Other Organic Fungicides :

(D_1) Glyodin : Wellman and Mecallan (1946) discovered about the fungicidal property of glyoxalidine derivatives which is now available under the trade name Glyodin in market. In temperate countries this fungicide is used to control Apple scab and other fruit diseases.

(D_2) Dodine/Cyprex : Dodine as a protectant fungicide became available in 1959. It does not harms bees. It can be safely mixed with ordinary fungicides and insecticides. It also has some eradicant property. Dodine is used to control Apple Scab and other foliar and fruit diseases.

(D_3) Quinone Compounds :

(i) Chloranil seed treating fungicide became available in the market under the trade name *'Spergon'* in 1940. Because of its disintegration in light, it is not used for foliar application.

(ii) Dichlone : After the success of Chloranil, Dichlone as a seed treating fungicide was launched in market in 1943 under the trade name *'Phygon'*. Besides its *seed protectant* property it is also used as a foliar protectant.

(D_4) Captan : As a protective fungicide captan was enlisted in 1949. It has been proved successful in the treatment of many diseases of fruits, vegetables and ornamental plants. Alongwith its use as a ***seed treatment*** fungicide it is also used to reduce post harvest losses caused by fungi in storage. Captan is also used for ***soil drenching*** @ 0.5% for protection against damping off.

(D_5) Folpet : Its physical and chemical properties are similar to captan and is sold under the trade name 'Phaltan'

(D_6) Difoltan : It is quite similar to Folpet and captan.

(D_7) Karathane (Dinocap) : It was first of all enlisted in 1954 to control *powdery mildew* disease in plants. Because of its solubility in oil, it is not used in oil based spray. It is a good substitute of sulphur and therefore used to control powdery mildew in sulphur – sensitive or Sulphur shy plants. Upto a certain extent it is also successful in controlling ***mites.***

(D_8) : Pentachloronitrobenzene (Quintozene) : It was enlisted in 1930 for the control of Soil borne pathogens and dry rot of potato.

Later on it came to be used to control *Rhizoctonia,*

Selerotium and other soil fungi. It is persistant in soil and cucurbits and tomato plants are sensitive to it. PCNB (Penta Chloro Nitro Benzene) is a *nematicide* also. It has mainly *antisporulant* and *fungistatic* property.

(D_9) Organic Tin Compounds : TPTA (Triphenyl Tin acetate) was enlisted under the trade name Brestan whereas TPTA and TPTH (Tripheryl tin hydroxide) under the trade name Denter. TPTA also has insecticidal property. It was enlisted in 1954 to control Potato blight.

(D_{10}) Oils : Nowadays oil-mist spray is used to control Sigatoka disease of Banana. Fungicidal property of oils is only due to physical reasons.

(E) Antibiotics :

(E_1) Streptomycin : Streptomycin at 100 ppm or more concentration has been found to be effective against bacterial seed-borne pathogen. But as there is greater possibility of development of resistant strains in bacteria, streptomycin is mixed with Oxytetracyclin (terramycin). This mixture or combination is called *Agrimycin*. Streptomycin is effective against both Gram-positive and gram-negative bacteria. It does not possess fungi-toxic property.

(E_2) Cycloheximide : It is obtained as a byproduct in the production of Streptomycin. Its trade name is Actidione. It is active against Phycomycetic fungus *Pythium debaryanum* but is ineffective against bacteria. Cycloheximide is a *systemic* fungicide and is easily absorbed by roots & leaves. Its effect persists for about 5 weeks after spray. But its production is expensive and there is little difference between effective concentration and phytotoxic concentration. It can also cause mutagenic effect in plants.

It is therefore not used for disease control in agricultural crops.

(E_3) Griseofulvin : It was first isolated in 1939 from *Penicillium griseofulvum*. It is obtained as a byproduct of several species of *Penicillium*. It is a systemic fungicide. Griseofulvin does not check the germination of spore but affects the growth of hyphae. Thus it is not a true fungicide. It does not harm bacteria. Griseofulvin is active against Powdery mildew.

(E_4) Aureofungin : It is a broad-spectrum systemic

antifungal antibiotic. It is used for seed treatment to protect from rot in storage.

(E_5) Blasticidin-S : It is produced from *Streptomyces griseochromogenes*. It is effective against many species of bacteria and certain fungi including *Pyricularia oryzae*. Because of its *growth inhibition* property, it is also used as a Chemotherapeutant.

(E_6) Kasugamycin : It is obtained from the culture broth of *Streptomyces kasugaensis*. It is selectively active against *Pyricularia oryzae* and *Pseudomonas* spp. Kasugamycin is more effective as an eradicant than as a protectant.

(F) Systemic Fungicides :

(F_1) Oxathiin : Oxathiin was developed by Von Schmeling and Kulka in 1966.

(i) Carboxin or DMOC/DCMO : Its trade name is *Vitavax*. It is a proven chemical against *Basidiomycetes fungi* (Smuts and Rusts). Fungi such as *Verticillium albo-atrum* and *Monilia cineraria* f. *americana* can also controlled by carboxin as they are sensitive to this systemic fungicides.

Vitavax is used for seed dressing and soil drenching in order to control *Loose smut of cereals* (internally seed borne) and *Rhizoctonia disease* of cotton and sugarbeet.

This chemical is not very stable & completely degrades in soil within 10-30 days. Vitavax is used to control Loose smuts *(Ustilago nuda, Ustilago avena)* and bunts.

(ii) Oxycarboxin/DNOCD/DCMOD : Its trade name is *Plantvax*. It is used in controlling diseases related to fungi imperfecti. The diseases caused by members of fungi imperfecti are – Early blight of potato, Alternaria leaf spot of crucifers, leaf blight of wheat, Leaf spot of groundnut, stripe disease of barley, leaf spot of rice (*Helminthosporium*) blast of rice, Ripe fruit rot end Dieback of chillies, *Wilt* of pigeon pea, wilt of cotton, wilt of linseed, fusarium *wilt* or Panana disease of banana, *Wilt* of sugarcane.

(F_2) Pyrimidine derivattives –

(i) *Methyrimol* - It is effective against powdery mildew of cucurbits, cinarea, chrysanthemum and sugarbeet.

(ii) Ethirimol – It is like methyrimol and effectively controls powdery mildew of Crucifers.

(F_3) Benzimidazole : It comes under the name of ***Benomyl*** or ***Bavistin*** or ***Benlate***. It is a *superior systemic fungicide* which acts as a good *eradicant* and *protectant*. It has ovicidal action against *mites* eggs. Benzimidazole is effective against certain fungal diseases of crops such as rice blast, diseases caused by *cercospora*; verticillium of cotton, powdery mildew and black spot of rose, but has less effect on *Helminthosporium* spp. & Phycomycetes.

(F_4) Chloroneb : It is almost completely *fungistatic* and relatively non-fungicidal in action. It is easily absorbed by plant roots and its concentration is more in root and lower part of the stem. It is therefore used in supplemented seed treatment and soil treatment to protect plants from seedling disease during planting. Chloroneb is active against *Rhizoctonia* spp. It can be mixed with most of the pesticides and organomercurials used in seed treatment.

(F_5) Thiobendazole (TBZ) : Although TBZ was enlisted as an *antihelminthic* but it is a broad spectrum systemic fungicide. This fungicide is transported from the roots to the leaves of plant and sometimes in the reverse direction also. It does not undergo disintegration in plant tissues. It is effective against Blue and green moulds of citrus fruits. When applied @120g/100kg it successfully controls seed borne bunt, *Fusarium nivale* and *Septoria nodorum*. Verticillium wilt can be successfully controlled if soil treatment is undertaken @30kg/ha.

(F_6) Terrazole/OM-2424 : It is an effective fungicide for the control of seed and seedling disease of Maize, Cotton, Sorghum, Soybean, bean, potato, tomato and *cucumis*.

(F_7) Organo-phosphorus compounds : This group includes compounds like Hinozan, Kitazin, Inazin etc. which are active against blast disease at a concentration of 400-500 ppm concentration. It becomes toxic at higher concentrations. It is extensively used in Japan. Among them Kitazin is an effective fungicide because of its excellent systemic behaviour.

(G) Organo–mercurial Fungicides :

Mercuric chloride is an effective Fungicide and bactericide. Because of its high toxicity it is not used to control plant diseases.

The general formula of organomercurial derivative is

R. Hg. X

Hydrocarbon Mercury Acid radical

The examples of Organo-mercurial fungicides are – ***Agrosan*** GN, Agrox, Aretan/**Agallol,** ***Ceresan,*** Mergamma, Parrygen, Panogen, Puraturb, Semessan. Because of their highly toxic nature great care is taken in their use. The treated seeds should never be used for human or animal consumption. Dry seed dressing contains 0.6-15% Hg whereas liquid dressing contains 0.6-2.0% Hg. Organomercurials mixed with γ-BHC or dieldrin is used to control insects attacking young seedlings.

(G) Formaldehyde – It was for the first time used in Germany for seed treatment during the last decade of 19th Century. Because of its lesser toxicity it was used as a substitute for $CuSO_4$. Inspite of this, use of Formaldehyde for seed treatment has several harmful effects.

Fungicides and their name

S.No.	Common Name	Other name
A.	**Metallic salts**	
A1	Copper Oxychloride	**Blitox,** Cupravit, Cuprox, **Fytolan,** Cupramar, Basic Copper Chloride, Coxysan
A2	Copper Sulphate	Blue vitriol, Bluestone
A3	Cuprous Copper Oxide	Fytomix, Perenox, Fungimar
B.	**Non-metallic Salts**	
B1	Sulphur dust	Brim Stone
C.	**Organo mercurials**	
C1	Ethyl mercury chloride	**Ceresan,** Granosan
C2	Methoxy ethyl mercury chloride	**Aretan, Agallol** (3%mercury equivalent) Agallol forte (6% mercury equivalent) Baytan.

C3	Phenyl mercury acetate + Ethyl mercury chloride in equal proportion	**Agrosan** G.N.
C4	Phenyl mercury salicylate	Mercusol, Merculine
D.	**Carbamate**	
D1	Benlate	Benomyl
D2	Carbendazim	Bavistin (Benzanidazole group)
E.	**Thiocarbamate**	
E1	Maneb	Dithane M-22, manzate, Manesan
E2	Mancozeb	**Dithane** M-45, Fore, **Indofil**
E3	Nabam	Chem Bam, Dithane D-14, Parzate
E4	Zineb	**Dithane Z-78**, Hescathane
F.	**Dithiocarbamates**	
F1	Ferbam	Fermate, Hexaberb, Tribungol
F2	Thiram/Thiuram	Arasan, Thiride, Mercuram
F3	Ziram	Cuman, Ziride, Zitox
G.	**Others**	
G1	Fentin Acetate	Brestan
G2	Captan	Merpan, Orthocide
G3	Fentiazon	Celditon
G4	Hinosan	Edifenphos
G5	Karathane	Arathane, **Dinocap**
G6	PCNB	**Brassicol**, Tritisan
G7	Plantvax	**Oxycarboxin**
G8	Vitavax	**Carboxin**
G9	Methan N sodium (Nematicide)	**Vapam, Metham**
H.	**Antibiotics**	
H1	Aureomycin	Acronize, Chlortetracycline
H2	Terramycin	Oxytetracycline, Biostat PA
H3	Streptomycin	**Agrimycin**
H4	BLA-S	Blasticidin
H5	Kasumin	Kasugamycin
*Plant	Growth Regulator Ethephon	**Ethrel**

*

19 Plant Disease Control

Till the appearance of disease symptoms the pathogen has taken command over the plant. In order to avoid such a situation it is essential to protect plants from disease i.e. protective and preventive measures should be undertaken. Therefore it is said prevention is better than cure.

Classification of Plant Disease Control Methods

- Plant Disease Control
  - Prophylaxis
    - Exclusion
      - Quarantines
      - Other regulatory measures
    - Eradication
      - Crop rotation
      - Sanitation
      - Elimination of over wintering hosts
      - Eradication of Hosts & Pathogens
      - Eradication of Alternate hosts
      - Chemical Eradication
    - Direct Protection
      - Chemical Prophylaxis
      - Environmental manipulation
  - Immunization
    - Genetic resistance
    - Chemo therapy

The control measures for plant diseases have been classified into two categories.

(A) Prophylaxis (B) Immunization

(A) Prophylaxis : include methods which protect the plant from the attack and infection by the pathogen or from the environmental factors which favour disease development. These methods have further been divided into three sub-categories.

(A_1) Exclusion : Method which prevents a disease from entering into a new area. For example – Quarantine and Inspection, embargo, certification etc.

(A_2) Eradication : This measure is taken for the elimination of the pathogen after its establishment on the host. It includes crop rotation, sanitation, elimination of alternate and over wintering hosts, elimination of pathogen from the seeds, tubers etc.

(A_3) Direct protection : The principle behind this measure is that noncompliance with it can result into infection. Fungicidal seed treatment methods are either eradicant or protective in nature. Spraying and dusting of fungicide on plant comes under direct protection. Other examples are – Controlling environmental factors in green houses and warehouses, altering the time of sowing & harvesting in order to make it favourable for the host and unfavourable for the pathogen, protecting plants from cold, frost, heat etc. and maintaining nutrient elements.

(B) Immunization : Immunization deals with development of disease resistance in plants. The host thus becomes capable of defending itself from the pathogen. Such characters are developed through selection and hybridization. Temporary immunization of plants can also be brought about by Chemotherapy. The host plant absorbs the chemotherapeutant and homogeneously circulates it in their body.

On studying the different methods of plant disease control three conclusions are derived –

(i) Direct action against the pathogen or the attack on the pathogen or exclusion.

(ii) Genetic modification of the host to resist disease or strengthening of the host.

(iii) The alteration in the environment to make it unfavourable for disease development or to modify the environment.

General Principles of Plant Disease control

(1) Avoidance of the pathogen
(2) Exclusion of the inoculums
(3) Eradication of the pathogen
(4) Protective measures
(5) Development of resistance in the host.
(6) Therapy of diseased plant.

Among these principles the first five are preventive measures and are adopted on the cooperative basis whereas the sixth one is curative measure.

(1) Avoidance of the pathogen : It includes the following measures

(a) Selection of Geographical area : A geographic area is selected on the basis of the favourable temperature and humidity requirement for a particular crop. Most of the species of fungi and bacteria develop & grow more & have more pathogenicity in humid areas in comparison to dry areas. For example – Smut and ergot disease of bajra are more in humid areas where the flowering stage prolongs in the rains for several days.

(b) Selection of field : Many soil borne diseases are controlled by proper selection of the field. It is quite possible that a particular field soil contains a pathogen species. In that case the particular crop is not sown in that field for several years. The causal organism of Red rot of sugarcane *Colletotrichum falcatum* survives in the soil for several months. Water drainage is also taken care of while selecting the field.

(c) Choice of the time of sowing : The susceptible stage of plant growth and the favourable environment for pathogen should not match at the same time.

(d) Disease escaping varieties : Certain varieties of crop due to their growth characteristics are able to escape from disease. This disease escaping characteristics of the crop is not genetic rather it is due to growth habits and time of maturation. Early maturing variety of pea is capable of escaping powdery mildew and rust.

(e) Selection of seed : To avoid seed borne diseases, healthy and disease free seeds are essential.

(f) Modification of cultural Practices : Cultural practices such as – distance between the plants, time and frequency of irrigation, transplantation time and method, mixed cropping, amount and property of fertilizer and compost etc. can be changed to reduce losses caused by the disease.

(2) Exclusion of Inoculum : It includes the following methods:

(a) Seed treatment : The pathogens present on the surface of seeds, tuber & graft etc can be excluded by chemical treatment. This helps in avoiding entry of the pathogen in new area.

Physical methods - *Jensen* for the first time used heat to control internal infection of potato tubers by late blight fungus *(Phytophthora infestans)*. It was observed that heat treatment of potato at 40^0C for 4 hours results into death of the internal mycelium. The **hot water treatment** method of Jensen was developed in 1887 which was used to control loose smut disease of wheat, barley and oats. Until the development of systemic fungicide hot water treatment was the only method to control loose smut. Hot water treatment is also effective in the control of nematodes.

Solar energy treatment to control loose smut was first developed by ***Luthra***. In this method seeds are first rinsed or soaked in water for 4-5 hrs. before drying them in scorching sun.

Hot air treatment for the control of virus in propagating stocks was first developed by ***Kunkal*** in Peach yellow.

Chemical methods :

Seed treatment with fungicide before transplanting is done with following objectives :

(i) To control disease caused by seed borne infection

(ii) To protect germinating seeds or seedlings from the attack of soil borne pathogens.

Chemicals used in Seed treatment

Chemical Seed Treatment

- Inorganic
  - Non metals
    - Sulphur dust
  - Metals
    - Mercurials e.g. Mercuric chloride, Mercurous chloride, Carbonate
    - Non-mercurials e.g. Basic copper carbonate, Red cuprous oxide etc.
- Organic
  - Mercurials e.g. Agrosan GN, Ceresan, Ethyl mercuric chloride, Phemyl mercuric acetate, Phenyl mercuric Urea, etc.
  - Non-mercurials e.g. Thiram, Oxanthiins, Carboxins, Chloranil, Systemic fungicides

Chemically treated seeds are kept dry during storage. Such seeds should undergo treatment at least one week before sowing. But seeds treated with liquid chemicals are not stored and the treatment is therefore performed just before sowing.

Seed dressing with organomercurials is potent enough to control many diseases except loose smut disease of wheat and barley. Therefore organomercurial is called a broad spectrum seed treating fungicide. Systemic fungicides are suitable to control loose smut of wheat & barley.

Types of seed treatment :

On the basis of nature and purpose seed treatment has been divided into three categories –

(i) Seed disinfection : This type of seed treatment is for the eradication of such pathogens which are internally seed borne i.e. they are established in the seed coat or deep tissues in the seed. Examples – Loose smut of wheat & barley, strike disease of barley, Rhizoctonia disease of tomato. Earlier only physical measures like hot water or solar energy treatment was used for the eradication of such diseases but now a days systemic fungicides like Plantvax/ oxycarboxin, vitavax, carboxin, Benlate/Benomyl, Bavistin etc. are used for the purpose.

(ii) Seed Disinfestation : Distruction of fungal or bacterial pathogens present on the seed surface is called seed disinfestation. The fungicides used in this process are either in powder or wettable form. Many externally seed borne diseases such as – covered smut of barley or oat, Loose and grain smut of Jowar, Wheat bunt etc. can be controlled by seed disinfestations. The fungicides used in seed disinfestations are as follows :

Cesesan, Panogen, Copper sulphate, Copper carbonate etc. These fungicides loose their effect when the seeds are sown in soil. Due to this these are not considered good seed protectant.

(iii) Seed Protection : Protection of seeds from soil borne pathogens during the process of seed germination is called seed protection. Pre-emergence Damping off disease in many vegetables can be controlled by seed protection. Organo-mercuric fungicides act as seed protectants. Other fungicides used as seed protectants are – Captan, thiram, Arasan, Semasan, Agrosan GN, Agallol, Aretan, Folpet etc.

(a) Systemic Fungicides are used for seed disinfection, seed Disinfestation and seed protection.

(b) Inspection and Certification : Crops grown for seed production are regularly inspected so that seed borne disease could be effectively controlled. Such disease free seeds are certified.

(c) Plant Quarantine : A plant quarantine can be defined as a legal restriction on the movement of agricultural commodities for the purpose of exclusion, prevention or delay in the establishment of plant pests and diseases in areas where they are not known to occur.

(d) Eradication of Insect Vectors : Insects serve as vectors for many diseases. Eradication of such insect vectors is essential for the control of pathogens. Examples of some diseases and their insect vectors are as follows :

S.No.	Insect – Vector disease/pathogen	Name of transmitting
1.	Aphids *(Myzus persicae)*	Potato leaf roll virus
2.	Leaf hopper	Maize streak virus, Rice dwarf disease virus; Tungro virus of rice.
3.	White flies *(Bemisia tabacci)*	Yellow mosaic of beans; Vein clearning of bhindi; tomato leaf curl
4.	Thrips	Tomato spotted wilt virus
5.	Mites	Wheat streak mosaic virus

(3) Eradication of the Pathogen : It includes the following principles–

(a) Biological control of plant pathogens : Decomposition of organic matter in the soil leads to intense microbial activity. Among them certain microorganisms have the potential to kill pathogens. In our country Root-knot nematodes and Black scurf of potato have been successfully controlled by organic soil amendments. Organic soil amendments come under biological control methods. This technique is helpful in controlling many soil borne diseases.

(b) Crop rotation : Crop rotation is essential for controlling soil borne diseases and pathogens.

(c) Removal and Destruction of Diseased Plant Organs

The following methods are brought into use –

(i) Roguing

(ii) Eradication of Alternate and Collateral hosts.

(iii) Sanitation of Fields

(d) Heat and Chemical treatment in diseased plants : This method is used to kill the resting structures of pathogen present on the host surface. This method is very effective in controlling diseases of fruit trees.

(e) Soil treatment : The main objective of this method is to inactivate pathogens and nematodes present in the soil. For this, different chemicals, heat, flooding and fallowing etc. like physical and chemical methods are used. For controlling nematodes volatile soil fumigants are mainly used. Chemical treatment is performed by any one of the following methods :

(i) Drenching of soil with solution or suspension

(ii) Broadcasting of dusts, powders or granules

(iii) Furrow application

(iv) Soil fumigation

(4) Protective Measures :

(a) Chemical treatment : The main objective of chemical spray, dusting and seed treatment is to form a protective poisonous layer on the host surface or to kill the parasites already present on the host surface.

(b) Chemical control of Insect vectors : Certain viral diseases are transmitted only through insect vectors. Therefore it becomes essential to kill these insect vectors.

(c) Modification of Environments : Hot and humid conditions are favourable for diseases and pathogens. Ploughing, frequency and amount of irrigation etc. change the environment upto a certain extent.

(d) Modification of Host nutrition : Host nutrition also affects diseases. Excessive nitrogen in plant promotes leaf diseases whereas excess of Ca and K makes the plant disease resistant. Balanced nutrient management in crops can help in reducing the intensity of many diseases.

(5) Development of Resistance in Hosts

Development of resistance in hosts is brought about by following

methods –

(a) Selection and Hybridization for disease resistance

(b) Through chemotherapy – when systemic fungicides and antibiotics are applied to plants in form of foliar spray or through roots., their toxic effects persists on crops.

(c) Through host nutrition :

(6) Therapy of Diseased Plants : Diseased plants are cured through following methods –

(a) Chemotherapy

(b) Heat therapy

(c) Tree-surgery – The diseased branches of trees are removed or the disease parts scrapped and fungicidal paste is applied on the wounded areas. This helps in checking infection. Important diseases of apple – Black stem, Brown stem and Pink disease etc. are controlled through surgery.

Soil treating chemicals : It is used for controlling such soil borne diseases which attack on seeds or seedlings. The examples of such chemicals are – Formaldehyde, Captan, Thiram, Zineb, Organo-mercurials, PCNB, Ethylene dibromide, vapam etc.

Seed treating chemicals : It is used for controlling seed borne diseases. Seed borne diseases are of two types –

(a) Externally seed borne diseases : For controlling these diseases, Chemicals such as Formalin, TMTD, Copper carbonate, Captan, Organo-mercurials (Agrosan GN and Ceresan) are used for seed treatment.

(b) Internally seed borne diseases : For controlling internally seed borne disease, hot water treatment and solar treatment are used.

Systemic Organic Compounds are effective chemicals for controlling both externally and Internally seed borne diseases.

Examples of Systemic fungicides : Oxanthin derivatives (Plantvax and Vitavax), Benlate, Bavistin, Demosan

For controlling air borne diseases, Foliar application of chemicals is more effective.

The common copper fungicides are : Perenox, Perelan, Blitox, Cuprokyt, Cuprosan, Fytolan. Its use is comparatively better than that of Bordeaux mixture.

Use of Organo-sulphur compounds such as Thiram and Dithiocarbamates (Zineb, Ziram) is a safer alternative for tender and sensitive foliage.

BACTERIAL DISEASES

Common Name	Particular Bacteria
1. **Citrus Canker**	*Xanthomonas citri*
2. Black rot of crucifers	*Xanthomonas compestris*
3. Bacterial blight of rice	*Xanthomonas oryzae*
4. Angular leaf spot of cotton or **Black arm disease**	*Xanthomonas malvacearum*
5. Leaf spot of chilli	*Xanthomonas vesicatoria*
6. Red stripe of sugarcane	*Xanthomonas rubriliniens*
7. Bacterial wilt of solanaceous plants/Brown rot of Potato/ **Ring diseases** of Potato	*Pseudomonas solanacearum*
8. Fire blight of Apple and Pear	*Erwinia amylovora*
9. Soft rot of carrot	*Erwinia crotovora*
10. Scab disease	*Streptomyces scabies*

MYCOPLASMAL DISEASES

Host Plant	Name of mycoplasmal diseases
1. Rice	Yellow dwarf disease
2. Safflower	**Phyllody**
3. Seasamum	**Phyllody**
4. Brinjal (Egg plant)	**Little leaf**
5. Citrus	**Greening disease**
6. Sugarcane	**Grassy shoot, white leaf**
7. Potato	Purple top; witches broom
8. Coconut	Lethal Yellowing

Note : Greening disease of citrus is actually a bacterial disease and causal organism is Gracilicutes gram negative bacteria. Previously it was considered as mycoplasmal disease.

VIRAL DISEASES

Host plant	Name of Viral diseases
1. Wheat	Mosaic streak
2. Maize	Mosaic; **vein enation**
3. Barley	Mosaic, Yellow dwarf
4. Bajra	Mosaic
5. Jowar	Yellowing
6. Rice	**Tungro diseases; Grassy stunt**
7. Sugarcane	**RSD** (Ratoon stunting Diseases)

8. Potato	**Potato necrosis;** Potato severe mosaic, Leaf roll; super mild mosaic
9. Tomato	**Leaf curl** : Mosaic; Black ring spot
10. Chilli	**Leaf curl** : Mosaic
11. Bhindi	**Yellow vein mosaic** (YVM)
12. Onion	Yellow dwarf
13. Urd	Leaf crinkle
14. Pigeon Pea	Sterility mosaic
15. Groundnut	**Clump disease;** mosaic; chlorosis
16. Tobacco	Leaf curl; yellow net vein (YNV); Ring spot
17. Banana	**Bunchy top**; mosaic, Banana streak
18. Citrus	**Tristeza** and **Quick decline**
19. Papaya	Distortion ringspot, mosaic, leaf curl.

Diseases caused by Nematodes

Names of disease and host plants	Particular nematode
1. Ufra disease of Rice	*Ditylenchus angustus*
2. Ear Cockle of wheat	*Anguina tritici*
3. Root lesion disease of chillies, coffee, cotton,tea, rice	*Pratylenchus* spp.
4. Plants affected by Golden nermatode/sugar beet nematode Host Plants – Potato, Brinjal, Sugarbeet, Beet	*Heterodera rostochiensis*
5. Plant affected by **Burrowing nematode** Host Plants–banana, rice,citrus	*Radopholus similes*
6. **Root knot disease**/Root gall disease Host plant – coffee	*Meliodogyne exigua*

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20 Disease-details Table

(1) RICE			
(i) Blast (Rich man's disease)	***Pyricularia oryzae***	Brown spindle.eye boat shaped lesion on leaf, neck rotting, discoloured nodes, partially filled grains; Heavy dose of nitrogen, high atm ospheric relative humidity (RH) = 86 – 98%) and night temp. of 20°C for few hours favour for disease/	Seed treatment with Agrosan GN,Ceresan/ Thiram @ 2g per kg of seeds; spray Zineb or mancozeb @ 0.25%; Grow resistant varieties – Tulsi, Rasi, Swarnadhan, IR-64 Nitrogen - management of field.
(ii) Bacterial leaf bligh (BLB) Or Bacterial leaf spot. (Poor man's disease)	***Xanthomonas oryzae***	'Kresek' occurs in early stage (Plant withers and dries up); In later stage blighting starts from the tip of the leaves to the tip of the base (downward), Straw turned yellow, partially filled grains, Yellowing **Bacterial Ooze** appears on the surface which dries up into bead-like incrustations (i.e. **Ooze test**); Problem under poor and N-deficient soil conditions.	Use disease free certified seeds, water drainage time to time; seeds treatment with Streptocycline 0.015% + ceresan 0.05%; 3-4 sprays of 75g Agrimycin-100 + 500g copper Oxy chloride in 500 lit. Water/ ha; Hot water treatment; use resistant varieties- Ajay, PR-10; Nitrogen management of field.
(iii) Tungro (Leaf Yellowing) (BLB & RTV are the Killer disease of Rice).	Rice Tungro Virus (RTV) vector-Rice green leaf hopper	Yellowing from tip & margin on older leaves, stunted growth, empty glumes & poor panicles with dark-brown colouration, Interveinal chlorosis.	Spray systemic insecticide Diazinon @1.5 kg a.i./ha; Rogue out diseased plants, slurry treatment of seeds with furadan 75% W.P. @0.13-g/kg seeds; use resistant varieties – Vikramarya.
(iv) Brown spot	***Cochillobolus miyabeanus (Helminthosporium oryzae)***	Many dark-brown elliptical spots on leaves; infects coleoptile of seedling and causes blighting; infected kernel shriveled.	Seed treatment with ceresan or Agrosan GN @2 g/kg of seeds, grow varieties like Bala, Krishna, Sabarmati, IR-204; Spray dithan M-45·@0.25% at 10-12 days interval.

(v) False Smut	***Claviceps oryzae sativae (Ustillaginoides virens)***	Infected kernels transformed into a large velvety, yellow olive green and more than twice in diameter than normal grains, Infected grains covered with powdery spore mass.	
(vi) Khaira disease	Zn-deficiency	Usually in nursery; chlorotic/Yellow patches at leaf base on both sides of midrib; restricted root growth and usually main roots turn brown.	Spray 5 kg Zn SO_4 + 2.5 kg lime per hectare at 10 DAS in nursery or $ZnSO_4$ @ 5 kg + Urea 2% in 1000 litre of water/ha at the sowing time.
(vii) Sheath blight	***Rhizoctonia solani***	Minor disease	—
(viii) Bakanae disease or Foot rot	***Gribbrelia fuglkuroi***	Minor disease	—
(ix) Udbatta disease	Fungal	Minor disease	—
(x) Ufra disease	***Ditylenchus angustus (nematode)***	Minor disease	—
(xi) Yellow dwarf	Mycoplasma	Minor disease	—
(xii) Pan Sukh	Dry physiological disease	Minor disease	Drain excess water; apply (NH_4) SO_4 @ 15-20 kg/ha.
(xiii) Grassy Stunt	Viral	Minor disease	—
(2) WHEAT			
(i) Rusts (a) Brown rust or Leaf rust (LR)	***Puccinia recondita tritici***	Round oval uredial pustules mainly on leaves and scatterd & Irregular; most widespread disease & most damaging in our country	Avoid late sowing, use high dose of K, Spray Zineb or mancozeb @0.2% Grow varieties like Sonalika, chhoti Lerma, UP-2003, HD-2285, UP-368, Girija, RH-124; Development of resistant variety through Conv-ergent breeding by using resistant genes viz., Yr, Lr & Sr is being tried.
(b) Yellow rust (YR) or Stripe rust	***Puccinia striiformis***	Lemon Yellow pustu-les in rows or long paralleles streaks; the pustules of yellow rust are smaller than those of Leaf rust;chiefly on leaves.	
(c) Black rust or Stem rust (SR)	***Puccinia gramimis triticl***	Elongated uredial pustules on stem, leaf sheath, leaves and earheads but stem is often most severally affected.	

(ii) Kernal bunt or Partial bunt	***Neovossia indica***	Called cancer of Wheat; grains partly converted into black sooty powder; gives rotten fish smell due to trimethylamine	Since it is soil borne, seed borne & air borne, hence only one solution is to grow resistant variety and seed treatment with mercury fungicide.
(iii) **Loose smut**	***Ustilago triticl (Ustilago nuda triticl)***	Early emergence of heads; Production of black powder in place of grain; Before ear-emergence only Sonalika is detected by yellowing flag leaves & withering; It can be distinguished at ear emergence; Internally Seed-borne. Factors conducive for spread : Wind for spore dispersal; Light rainfall at flowering time; Openness of the flowers; suitable temp. around 18-20^{0}C for germination of chlamydospores; Atmosphere should not calm and quiet. Max infection at when plant raised at 21^{0}C; No infection at 29^{0}C.	Seed treatment with vitavax @2.5g/kg of seed, solar heat treatment; Hot water treatment, Raise windbreak plantation to restrict its spread.
(iv) **Ear Cockle**	***Arguina triticl*** (nematode)	Leaf blades generally twisted; infected ears shorter and remain green longer; awans more spreading; affected grains transformed into one or more small galls.	Floatation of Seeds in 20% salt solution; Rogueing; use clean seeds.
(v) **Tundu disease** or Yellow ear rot or Sehum disease	***Corynebacterium tritici (bacteria) + Anguina tritici (nematode)***	Curling of affected plant leaves; bright yellow **slimy ooze** (due to bacteria) on leaves and inflorescence; **Agglutinized Inflorescence;** seeds not formed; grains transformed into small hard galls.	Floatation of Seeds in 20% salt solution; Rogueing; use clean seeds.

(vi) **Molya disease** or cereal root eelworm	***Heterodera avenae (Cyst nematode)***	Stunting, Pale Yellow sparsely growing seedlings; roots showing knots containing nematode cysts.	Crop rotation.
(vii) Flag smut	***Urocystis tritici***	—	—
(viii) Hill bunt	***Tilletia foetida or Tilletia caries***	—	—
(3) BARLEY :			
(1) Covered Smut	***Ustilago hordei***	Smutted head; grains replaced by black agglutinised spore masses & Covered by persistent white pape-ry membrane. Factors for spread – (a) amo-unt of moistuse (b) suitable temp. (c) Depth of planting when seeds are planted deep; it take too long time to emerge at the surface. Its dispersal is only at time of harve-sting because chlamy-dospore sticks to seed.	Externally seed borne hence easy to control; Seed dressing with AgrosanGN @2.5g/kg Seeds.
(ii) Loose smut	**Ustilago nuda**	Same as of wheat	Same as of wheat
(iii) Powdery mildew	***Erysiphe graminis var. hordei***	Cottony growth on both the leaf surface (but on lower surface in downy mildew); later on powdery deposits of conidia; necrosis at powdery spot' Ectophytic; Favourable condition Winter season. Cold and dry weather; control through S-fungicides.	Spray 'S'-Fungicide grow resistant variety.
(4) JOWAR :			
(I) Downey mildew	***Sclerospora sorghi***	Downy white growth on lower surface with yellowing on upper surface on young leaves i.e. chlorosis at downy spot; later on shredding of leaf & stunted growth; Endo-phytic; Favourable condition-Monsoon mainly cold & moist weather; control through Cu-containing fungicides like Bordeaux mixture (BM) Zineb etc.	Grow resistant variety. Seed treatment with Agrosan G.N./Ceresan@ 2.5g/kg seed spray maneb or Zineb @0.2%

(ii) Grain Smut	***Sphacelotheca sorghi***	Grains transformed into elongated cylindrical structures consisting of black spore masses.	Seed treatment with finely powdered Sulphur @5g or Agrosan G.N. @2g/kg seed.
(iii) Leaf rust	***Puccinia purpurea***	Bright Purpled spot on leaf surface mainly on lower surface; more severe after flag emergence.	Grow resistant variety like CSH-1, 2 etc; spray Dithan Z-78 @0.2% at 10-12 days interval.
(iv) Anthracnose or Bed leaf spot (BLS)	***Colletotrichum graminicola***	Brown spots with whitish or purple centres on lower leaves; affects both seedling as well as matured plants.	Grow resistant varieties i.e. CSH-1, CSH-2 etc; Seed treatment with Agrosan G.N.: Spray Zineb @ 0.2% ; Weed out Johnson grass (Collateral host)
(v) Head smut	***Sphacelotheca relliana***	Part of Entire floral structure transformed into smutted galls.	
(vi) Long smut	***Tolyposporium ehrenbergii***	Few grains transformed into long cylindrical and slightly curved bodies	
(5) BAJRA			
(i)Downey mildew or **Green Ear disease (ERD)**	***Sclerospora graminicola***	Ear transformed into green leaf like or leafy whorl type structure. Essential factors for germinating oospores are (1) Good air supply (2) Low soil moistuoe (3) 20-25^{0}C temp; it means oospore req-uires weathering; More conducive is Light soil; According to **Sateulla & Thirumalachar** (1956) – at 15-20^{0}C and 90% RH (Moisture near saturation) sporangia were formed. According to Wetson, asexual stage of it is not found in India.	Roguing of diseased Plant, Grow hybrid resistant varieties i.e. HB-3 Spray 0.2% Zineb.
(ii) Ergot	***Claviceps fusiformis***	First appear on the ears in the form of honey like pinkish liquid; Liquid turns brown & sticky; Sclerotia (ergot i.e. pinkish liquid) appears as brown to black later on and elongated structure.	Avoid late planting; Floating of seeds in 2% salt solution, spray Ziram @ 0.15% at boot leaf stage.

(iii) Smut	***Tolysporoium penicillaria***	Affected kernels green & larger in the beginning but later turns to black.	Remove smutted ears; spray vitavax @0.25% Follow three year crop rotation
(6) MAIZE			
(i) Whit bud of Maize	Zn-deficiency	Apical portion of leaf becomes white	Apply $ZnSO_4$ @ 20-25 kg/ha at sowing time.
(ii) Seed rot or sedling blight	***Pythium aphanidermatum; Fusarium monilliformis; Rhizoctinia spp.***		Seed treatment with captan or Thiram @2.0g/kg of seeds.
(iii) Black bundle	***Cephalosporium acremonium***	Decay of Vascular bundle; wilting of leaves & ultimately wilting of plants; black spots in the middle of vascular bundle i.e. black spot on the cut ends of the stalk.	Use resistant hybrids; seed treatment with Bavistin @2g/kg seed (systemic fungicide)
(iv) Bacterial Stalk rot	***Erwinia crotovorta var zea.***	Basal inrternodes become soft, discolour and starts decaying; alcoholic smell in the field.	No water logging; injury to plant avoided; Roguing of affected plant.
(v) Charcoal rot	*Macrophomina phaseoil*	Shredding of the pith in the stalk, Black dot on the rind and inside the stalk; lodging of the crops in severe cases	Avoid water strees after the flowering of the crop.
(vi) Turcicum leaf blight	***Trichometasphaeria turcica (Helminthosporium turcicum)***	—	—
(vii) Maydis and carbonum leaf blight.	—	—	—
(viii) Banded leaf & sheath blight	—	—	—
(ix) Brown stripe downey mildew	—	—	—
(x)Pre-soaking stalk rots.	—	—	—

(7) GRAM			
(i) Fusarium wilt	***Fusarium Oxysporum f. sp. ciceria (4 races)***	Stunted growth; yellowing of leàves, withering of plants; Main root turns black	Use of resistant genotypes viz. Pusa-212, Phule G-5; Avrodhi; Seed treatment with Bavistin + thiram (2g + 1.5g/kg seedf); solorization of soil with polythene sheets or deep ploughing and exposure to solar radiation; Late & deep planting.
(ii) Sclerotinia blight	***Sclerotinia sclerotiorum***	Plants become yellow then brown and ultimately dry; All plant parts are affected except roots.	Soil treatment with captan @10 kg/ha; Grow resistant,varieties
(iii) Ascochyta blight	***Ascochytarabie (2 races & 1 biotype)***	-do-	Use resistant genotype viz Gaurav; seed treatment with Bavistin & thiram (1:1) or Hexacap @ 3 g/kg seed controls primary infection; spray Dithiaron, @0.1% Indofil M-45; captafol @0.2 & Captan @0.2% for excellent control.
(iv) Botrytis grey mould	—	—	resistant var-Dhanush.
(v) Leaf spot & root rot	***Alternaria circinans & Fusarium monilliformae***		
(8) ARHAR			
(i) Fusarium wilt	***Fusarium oxysporum f. sp. udum***	Most destructive soil borne fungal disease wilting of leaves & plants; lateral roots completely rotten; Tap root become black on the surface & move upward; wilting branches arrive from such blackened area; Black streaks on wood below the bark; disease spread in a circular fashion around the first wilted plant.	No chemical control (i) Follow mixed cropping. Viz Arhar + Tobacco & Arhar + Sorghum. Tobacco liberates chemical injurious to Pathogen & Sorghum's root exudates HCN which is toxic to Fusarium. (ii) Soil amendments with green manuring & use of oil cakes. (iii) Crop rotation with sorghum or tobacco or fallow for 1-2 years.

(ii) Sterility mosaic	Sterility mosaic virus (SMV) Vector-Mite ***(Aceria cajani)***	Plants become light greenish bushy; no flowers & fruits	Roughing of Perennial & Self grown plants; only ICPL-151 is resistant in early maturity group; use of acaricide viz Tedion, Morest, Kelthane @1.0% Besides, seed dressing with carbofuran as 25% (Furadan 3G) and seed treatment with 10% Aldicarb or its soil application @1.5 kg a.i./ ha.
(iii) Phythophthora stem blight	***Phytophthora drechsleri f.sp. cajani***	Serious disease in high humidity and poorly drained soil i.e. state of W.B.; short duration varieties are more susceptible.	Seed treatment with Metalaxyl (1.75g a.i./kg seed) followed by 1 spray of Metalaxyl 25 WP (at 1000 ppm) 30 DAS; proper drainage & Planting on ridges.
(iv) Alternaria leaf blight		Serious in post-rainy season	Resistant genotypes are DA-2, DA-11 & Pant A-3.
(9) SOYBEAN			
(i) Yellow Mosaic	Yellow mosaic virus (YMV) Vector-white fly ***Bemisia tabacci***	Yellow mosaic mottling of leaves accompanied with crinkling & reduction in size; stunted plants & few pod setting.	Use resistant variety; spray metasystox 25 EC @1 kg/ha in 1000 lit. of water at 10 days interval; Roguing of diseased plants.
(ii) Anthracnose (pod blight)	***Colletotrichum truncatum***	Pod becomes yellowish & later turns to brown; seed formation seriously affected	Use resistant variety viz Bragg. Spray Zineb @0.25%
(10) GROUNDNUT			
(i) Tikka disease & rust or Cercospora leaf spot & rust (CLS)	***Phaeoisariopsis personata (Cercospora*** personata & ***Cereospora arachidicola) Rust- Puccinia arachidis***	Small dark brown spots and Pre-mature leaf shedding. In case of personata, brown spots are regular & not more than 0.6 mm in diameter but of arachidicola, there are irregular spots.	Spray Bavistin @0.05% + Dithan M-45 @0.2% 2-3 times at 2-3 weeks intervals starting from 4-5 weeks after planting.
(ii) Collar rot & dry root rot	***Aspergillus niger*** (collar rot)	Attack at seedling stage at the base; black spores are seen at root	Seed treatment with 5g thiram or 3g or Dithane M-45 or 2g Bavistin Per kg kernels; crop rotation
(iii) Stem rot	***Sclerotium rolfsii***		Seed treatment same as of collar rot.

(iv) Bud necrosis	Vector-Thrips Tomato Spotted wilt virus (TSWV)	—	Spray 400 ml. Rogor or 360 ml Methyl demeton/ha; Adopt cultural methods like early planting closer spacing, & intercropping with millet crops; Tolerant varieties are kadiri-3, ICGS-II, ICGS-44.
(11) SESAME			
(i) Phyllody	Mycoplasma vector-leaf hopper	Green leafy floral parts and profuse branching	Spray Metasystox : 1 ml/lit. water
(ii) Leaf curl	Nicotiana virus 10; vector aphid	Downward curling of leaves	Soil application of phorate granules @10 kg/ha; spray Metasystox @1ml/lit. water .
(12) RAPE & MUSTARD			
(i) Alternaria blight	***Alternaria brasicae***	Causes average loss 36%; it causes 10-70% damage while aphid pest causes damage 35-73%; concentric black spots on leaves, stems & pods.	Collect & burn disease debris; remove weeds like coriander; spray captafol (Difoltan, Foltaf) @1.5 kg/ha or Dithane M-45 @ 2 kg/ 1000 lit. Water at 15 days intervals starting from 40-45 DAS; Hot water treatment of 50^{0}C for 10 minutes of seeds.
(ii) White rust.blister	***Albugo candida***	White or yellow pustules of variable sizes & shapes on lower surface of leaf; infection covers all parts except roots.	Clean cultivation; remove and burn affected plants; spray zineb @0.2%, captafol (Difoltan, Foltaf) or copper oxyflouride (Blitox 50 @ 1.5 kg/ha) at 15 days interval.
(iii) Downey mil-dew	***Pernospora brassicae***	Yellow & irregular spots on upper surface & white growth on under surface of leaf; malformed inflorescenece.	Spray 0.2% Zineb at 10 days interval.
(iv) Sclerotinia rot & club roots	—	—	Use long term crop rotation; control of cruciferous weeds; lime sulphur @1 kg/m^2.

(13) SUNFLOW ER			
(i) Alternaria blight or Leaf spot	***Alternaria hellianthi***	Small oval spots on leaves	Spray Mancozeb (Indofil M-45) Zineb (Indofil Z-78) @0.25%.
(ii) Rust (iii) Root & collar rot	***Puccinia hellianthi*** ***Sclerotium rolfsii*** ***Rhizoctonia bataticola***	—	Seed treatment with Brassical followed by Thiram and Mancozeb reduces root and collar rot
(iv) Downey mildew	***Plasmopara halatedil***	—	Seed treatment with APRO 35 SD (metaloxyl Comp) @ 6g/kg seed
(14) Cotton			
(i) Bacterial blight or Angular Leaf spot or Black arm (ALS)	***Xanthomonas malvacearum***	Major disease of cotton; angular and water soaked lesions on leaf & stem.	Spray Streptocycline + copper oxychloride; seed treatment with agrimycin 100; destroy debris.
(ii) Fussarium wilt	***F. Monilliform f sp. vasinf-ectum***	Vascular tissue beco-mes brown; only scatte-red plant affected	Grow resistant variety like American cotton; apply K + O.M.
(iii) Anthracnose	***Colletotrichum indicum***	Dark brown spots on the stem below soil surface and on roots; circular & water soaked spots on bracts and spread to bolls.	Seed treatment with ceresan/Agrosan G.N. @2.5 g/kg Seed; spray Blitox @0.2%
(iv) Myrothecium leaf spot	***Myrothecium roridum***	—	Spray carbendazin 0.1% or copper oxychloride (0.2%)
(v) Tirak	Physiological	Premature defective openings of bolls & shedding of leaves	Late sowing, apply extra water at flowering & fruiting in sandy soil.
(vi) Root rot/Dry root rot/Sore shin	***Rhizoctonia bataticola*** ***Macrophomina phaseoli*** ***Rhizoctonia solani***	—	Mixed cropping with Moth (Phasaolus aconitifolium)
(vii) Grey mildew or Dahiya disease	***Ranulariaareola***	Serious only in desi cotton; cloudy weather followed by rains and temp. 24-26^{0}C favours this disease.	Dusting of 'S' or spray 0.1% carbendazim or 0.2% kalthane.

(viii) Stenosis (small leaf)	virus	Extreme stunting of the aerial organs.	—
(ix) Verticillium wilt	—	—	—
(14) SUGARCANE			
(i) Red rot	***Collectotrichum falcatum***	Red rot inside the stalk; red area traversed by white band; alcoholic smell from field.	Setts treatment with 0.25% Agallol or Aretan (1:100) solution; avoid ratooning; use healthy setts; Heat treatment.
(ii) Grassy shoot **disease (GSD) or (Albino)**	Mycoplasma	Excessive tillering, sprouting of lateral buds	Use healthy setts, Hot water treatment or Most hot-air therapy or aerated stem (50^0C for 1 hr.)
(iii) Ratoon Stunting disease **(RSD)**	Ratoon stunting virus (RSV)	—	Heat treatment, application of 'S'
(iv) Sett rot or Pineapple disease (v) Rind disease	—	—	—
(16) Potato			
Late blight	***Phytophthora infestans***	Bright brown & irregular patches starts from leaf tip or leaf margin; later on turned in brownish black patches; Ground leaves show symptom first; in favourable condition entire vegetative parts are killed within a day hence called blight; in unfarourable environment infected area becomes brittle & detached; **continuous high humidity** and relatively **low temp.** are favourable condition. In Indo gangetic plains only mode of survival is infected tubers stored at low temp.	Healthy seed material, high ridging to reduce Infection, delayed harvesting because of high temp & the above parts is dried away. Due to labour intensive Bodeaux mixture is not used; Blitox 50 is not also used; spray Maneozeb/ Zineb @ 2.0 – 2.5 kg.10 lit. of water/ha; 2-3 sprays at 15 days interval; tuber treatment with mercuric chloride (1:1000 in water) ; Use resistant variety like kufri Alankar, kufri Jyoti & Kufri chandramukhl developed by CPRI, Shimla.

(ii) Early blight	***Alternaria solani***	Concentric ring or target board appeared on leaf lamina; spots irregularly distributed; No any particular favourable condition hence it is widely distributed; collateral host is Tomato.	Spray Zineb/Maneb @0.2% Sort out infected tubers.
(iii) Black scurf	***Pellicularia filamentosa (Rhizoctonia solani)***	Surface of tuber covered with black in-crustations (Sclerotia of pathogen), growing tips of tuber sprouts are killed.	Tuber treatment with mercury chloride (1: 1000); soil treatment with Brassicol @20-30 kg/ha as furrow application.
(iv) Wart	***Synchytrium endobioticum***	Appearance of tumours or warts on tubers, stems & stolons.	Grow resistant variety.
(v) Black heart	***Oxygen*** starvation (Physiological)	Particularly of tubers at the bottom of deep piles kept for a long period; the tissue of the cut tuber turns pink on exposure, later turning dark brown or black.	Provide proper storage conditions with adequate ventilation.
(vi) Charcoal rot	***Macrophomina phaseoli***	The roots become brown & rot; the bark of stem becomes ash-coloured ; black sunken areas are formed around the stem end of the tuber.	Eearly harvesting; tuber treatment with Agallol/ Aretan grow resistant variety.
(vii) Black leg & soft rot	***Erwinia carotovara***	—	—
(viii) Scab	***Streptomyces scabies***	—	—
(17) TOBACCO:			
(i) Tobacco mosaic	Virus	Mosaic mottling, blistering & puckering of young developing leaves.	Strict sanitary measu-res; spray 1% tannin acid; Roguing.
(ii) Damping off	***Pythium aphanidermaum***	Seedlings rot at collar region	Preseeding application of Metalaxyl MZ @2.16 kg/ha followed by 2-3 post-emergence application.

(iii) Tobacco Leaf curl (TLC)	Tobacco leaf curl virus (TLCV) Vector-whitefly	Okra & castor support the growth of vector but are non-hosts of TLCV while clusterbean, Seasame, sunnhemp & chillies are alternative hosts of TLCV.	Clean the alternative hosts & other weeds.
(iv) Frog eye leaf spot (v) Black shank			
(18) TOMATO			
(i) Tobacco mosaic	Virus	Same as of tobacco	
(ii) Late blight		Same as of Potato	
(iii) Early blight		Same as of Potato	
(iv) Leaf curl	Virus	Curling of leaves, thick & leathery leaf	Spray systemic insecticide Dimethoate 0.1% at one week interval before fruit ripening.
(vi) Blossom end-rot (Buck eye-rot)	***Physiological due to Ca deficiency, uneven moisture supply***	Black, sunken, necrotic lesions, Water-soaked at the blossom end of green or ripening fruits.	Folior spray of Ca SO_4 @ 0.4.0.5% avoid irregularity in moisture supply; spray captafol 0.3% at 10 day interval.
(vii) Cracking	Physicologial due to B-deficiency of heavy rain/ irrigation after a long dry spell	Radial and concentric cracking at the upper side of fruit.	Spray Borax @0.2% in soil @15-20 kg/.ha.
(19) Brinjal (Egg plant)			
(i) Phomopsis blight or fruit rot	***Phomopsis vexans***	Soft & watery soaked on fruit; blight of foliage; fruit rot.	Seed treatment with carbendazim @1 g/kg of seed; Dip seedling in 0.5% carbendazim @ 1 g/kg of seed; Dip seedling in 0.5% carbendazim for 30 minutes before transplanting followed by 2 spraying of 0.05% Bavistin at interval of 10-15 days after one month after trans-planting; Crop rotation.

(ii) Little Leaf	Mycoplasma	Tinny Yellow leaves & bushy growth	Roguing: apply thimet 10G @10kg/ha in nursery
(iii) Wilt	***Pseudomonas solanacearum***	**Vascular bundle (V.B.) becomes brown**	Crop rotation, grow resistant variety.
(iv) Damping off	***Pythium sp.***	Rotting of seedling	Rotation of seedbed; hot water treatment; Drench nursery with captan.
(v) Broom rape (Orobanche)	Flowering root parasite		
(20) OKRA/ BHINDI :			
(i) Yellow Vein mosaic (YVM)	Virus (YVMV) vector – white-fly	Yellowing of leaf vein and ultimately dries; vector persist on wild host (i.e. **Hibiscus tetraphyllus)**	Removal of wild host plant; spray malathion; grow resistant variety like Pusa Savani spray sulphax W.P. @ 2 kg/ha.
(ii) Powdery mildew	***Erysiophe cichoracearum***	White powdery coating	Spray Sulphax w.p. @2 kg/ha
(iii) Damping off			
(21) CHILLIES			
(i) Damping off	***Pythium aphanidermatum Phytophthora sp.***		
(ii) Wilt	***Fusarium annum***		
(iii) Anthracnose (Ripe rot dieback)	***Collectotrich-um capsici***		
(iv) Leaf curl	Virus		
(22) CABBAGE (All Brassica spp.)			
~~(i)~~ White blister	Same as of Rapeseed		
(ii) Browning of Cauliflower	Boron (B) deficiency	Brown curd, hollow stem	Apply Borax @ 10-15 kg/ha in soil or spray 0.2-0.3%.
(iii) Whiptail of cauliflower	**Mo-deficiency**	Thick, green & leathery leaf and no curd.	Apply 1-2 kg Sodium or Aluminium molybdate.

(iv) Club-root (Finger & toe disease)	***Plasmodiophora brassicae***	Club-shaped roots (spindle-shaped or spheroid growths)	Seedling treatment with mercuric chloride in @ 125 ml per 100 seedling.
(v) Black rot	***Xanthomonas compestris***	Blackening of V.B.; Blighting from leaf margin to midrib in V-shaped	Hot water treatment at 50^0C for 30 minutes; roguing.
(23) APPLE			
(i) Scab	***Venturia inaequalis***	Scattered, circular brown spots with dendritic margin on undersurface of leaves; dark brown spots on fruits.	Pre-blossom spraying with lime sulphure (1:60) or Benomyl at fortnightly interval.
(ii) Bitter rot	***Glomerella cingulata***	White powdery growth	Remove affected fruits; apply Bordeaux mixture (4 : 5 : 50)
(iii) Powdery mildew	***Podosphaera leucotricha***	Rotting of premature fruits & continue upto storage	Spray Bordeaux mixture, Karathane E.C. (0.05% or carbendazim (0.05%).
(iv) Black canker	***Sphaeropsis malorum***	Cankerous, elongated corky lesion on stem; bark cracks, peels off	Only control is Pruning
(24) MANGO			
(i) Malformation	***Fusarium monilliformae var. subglutin-ana (Previously considered mite, Virus & Physioligical)***	Vegetative and floral malformationl bunchy top appearance;more around cities or settlement than in open country-side due to particulate type of pollution.	Pruning; spray captan; single spray of NAA or planofix in the conc. Of 200 ppm by deblossom-ing at bud burst stage.
(ii) Anthracnose	***Colletotrichum gloeosporiodi-des***	Dark brown spots on leaves	Spray 1% Bordeaux mixture or Metalaxyl
(iii) Black tip	B-deficiency near brick-kiln	Basal end of fruits rots and turns black	Spray Boarax @ 0.6% thrice in a year; Brick kiln about 15m high or orchard away from brick-kiln.
(iv) Fruit drop	Deficient nutrient for-many of the developing embryos may also be imp-ortant factor leading to post-fertilization drop.	Fruit drop is a contin-uous process; occurs primarily at 2 periods; first drop at from fruit set to 20 days after and 2^{nd} drop when develop-ing fruits are 28-35 days of after pollination & fertilization.	Apply 400 ppm & NAA at 30 days followed by GA_3

(25) GAUVA			
(i) Fruit canker (Grey blight)	***Pestalotia psidiia***	Generally occurs on green fruits & rarely in severe form raised cankerous spots on fruits & leaves; fruit becomes hard, mal-formed & mummified.	3-4 spraying of 1% Bordeaux Mixture (BM)
(ii) Anthracnose	***Collectotrichum psidii***	Causes dieback, twig blight, winter tip or fruit spots.	Spray Difoltan 0.3% followed by Dithan Z-78 0.2% at one month interval.
(iii) Gauva wilt	Still unresolved Scanty information on its etiology.	Wilting in two forms viz dieback or slow wilting & quick wilting. In dieback, plant starts dying from the top down words whereas in quick wilt, plants die immediately after the infection is noticed.	Conrtrol measures are not clearly understood; guava sp. Psidium cattliennam; P. Molle P. quidanense, P. friedrichallanum & Phillipine guava are resistant to wilt and may be used as root stock
(26) PAPAYA			
(i) Ring spot or Papaya ringspot or Distortion ringspot	Ringspot virus (RSV) Papaya ringspot virus (PRSV) Distortion ringspot virus (DRSV) Transmission by mechanical sap. Inoculation and aphid vectors.	ELISA test confirmed that the mosaic virus of India belongs to papaya ringspot virus (PRSV); PRSV is a serious disease, infected leaf rolls upwards along the margins distinct round spots on main stem which turns into elongated streaks in advance stages, elongated dark green streaks on leaf petiole & upper half of the stem; malformation in winter; yellow spots & yellow rings with solid green center on matured green fruit.	No reistant variety to PRSV. Spray malathion to control aphid vector *(Aphis gossypill A. craclvora, Myzus persicae)*
(ii) Leaf curl	Viral	Curling, crinkling and distortion of leaf.	Uprooting of infected plants at early stage.
(iii) Papaya mosaic	Viral	Faint chlorotic spots on leaf surface followed by vein clearing, puckling & mottling of young leaves; in extreme cases leaf blade distorted & modified into shoe string; identical to Ringspot.	Same as of ringspot

(vi) Stem & Foot (Collar) rot	***Pythium aphanidermatum***	Water soaked patches & swollen collar of the stem.	Good drainage & spray 1% Bordeaux mixture (BM)
(27) BANANA			
(i) Panama wilt	***Fusarium oxysporum var. cubense***	Progressive browning & falling of leaves. Black streaks on under ground stem, Serious on Rasthali group of banana & Cavendish group is not susceptible.	Use disease free suckers; crop rotation; eradicate affected plants.
(ii) Bunchy top	Virus (BBTV) Banana Bunchy top virus Vector ***Pentalonia nigronervoga***	Leaves shot & narrow; bunched together at top	Use virus free sucker; roguing.
(iii) Konkan disease or Banana bract mosaic	Viral (Banana bract mosaic virus –BBMV)	Disease of Nendran banana in Kerala; spindle shaped pattern in unusually red coloured pseudostem; darkstreak on petiole base) reddish streaks on bracts & undersized fruit.	
(iv) Banana Streak disease	Banana Steak virus (BSV) Vector : Mealy bug ***(Planococcus citri)***		
(v) Sigatoka or Leaf spot	***Mycophaerella musicola***	Prevalent in humid tropics or coastal regions.	
(vi) Cigar-end disease	***Stachylidium theobromae***		
(vii) Black finger	***Macrophomina musae***		
(28) CITRUS :			
(i) Citrus Canker	Xanthomonas compestris pv citri	Most serious disease of acid lime; small brown raised corky outgrowths on leaves, twigs, fruits	Prune & burn; use only disease free planting material spray 1% B.M.
(ii) die-back or wither tip or twig blight	***Collectotrichum gloeosporiodies Diplodia natelansis Fusarium sp.***	Dieback of young twigs; black dots on dead tissues.	Prune & apply Bordeaux paste paint to cut ends; spray with Zn-Cu lime.

(iii) Gummosis (Broom rot)	***Phytophthora palmivora***	Ruptured lengthwise bark, exudes gum	Spray 0.1% aurofungin
(iv) Greening	Gracillicuts gram negative **bacteria** (previously considered mycoplasma) Vector- ***Diaphorina citri***	Yellowing of midribs & lateral veins of leaves;	Drenching with tetracycline; spray B.P. 101 (500 ppm)
(v) Tristeza	Citrus tristeza virus (CTV) vector-***Toxoptera citricida***	Gradual decline in vigour	Use resistant root stock viz. Rangpur line.
(vi) Decline/chlorosis	Insufficient soil moisture and nutrition	Yellowing and gradual reduction in the size of the leaves; die back of the twigs followed by decline and gradual death	
(vii) Root rot	***Phytophthora palmivora Phytophthora citriphthora Phytophthora parasitica Phytophthora nicotianae var. parasitica***	Use of tolerant root stock; Drenching with Ridomil and Foltaf.	
(viii) Pink disease	***Pellicularia salmonicolor***		

❋

21 Genetics : An Introduction

The word "Genetics" has been derived from the Greek root 'gene' which means to grow into or 'to become'. The term 'Genetics' was coined by W. Bateson. Bateson also coined the term homozygous and heterozygous.

Genetics is the study of heredity and variation.

Heredity means traits or characteristics transmitted from generation to generation. It means such traits are fixed for a particular individual.

Variation means difference. Variation may be hereditary or environmental.

Hereditary variations refer to variations in inherited traits. Such variations (hereditary) are transmitted from generation to generation. The cause of hereditary variations is sexual reproduction & mutation. Mutation is the sudden, permanent & heritable change. The term mutation was described by *Hugo de Vries* (1901) while working on *Oenothera lamarckiana* (evening primrose).

Environmental variations refer to variations in environment & are merely due to environment. Such variations are temporary and are not transferable from generation to generation.

In order to make definite distinction between hereditary and environmental variations, Johannsen (1909) formulated the 'genotype-phenotype concept'. According to this concept the genotype of an individual represents sum total of heredity. Phenotype represents features produced by interaction between genotype & enironment.

genotype = genetic make up

phenotype = f (genotype + environment)

Phenocopy : When the two phenotypes are the same produced from the two different genotypes & different environments, one is called phenocopy of other. e.g. *Drosophila melanogaster.*

The terms 'gene', genotype & phenotype were coined by Johannsen. The term 'gene' was coined for mendelian factor.

'Gene' is chemically a segment of DNA that controls the synthesis of polypeptide (enzyme).

Gene :

(i) It is hereditary unit.

(ii) Genes are linearlly arranged on the chromosome. It means chromosome is the bearer of genes. Gene is the passenger on the chromosome i.e. Gene is the functional unit of hereditary material which is located on the chromosome. This is known as **chromosomal theory of inheritance** postulated by **Sutton & Boveri.**

(iii) Mendel called it a factor

(iv) Gene remains in pair.

(v) Two forms of gene < Dominant / Recessive.

Today gene is defined as "genetically functional segment of DNA Filament".

Genetic materials are DNA & RNA

DNA : Deoxyribose nucleic acid

RNA : Ribose nucleic acid

Genetic material in most of the organism is DNA. 'DNA is the genetic material and not the protein' was described by O.T. **Avery,** C.H. **Macleod** and M.Mc **Carty** on *E.coli* in 1944.

First time In vitro synthesis of DNA : **A. Kornberg**

Artificial Synthesis of gene which coded for alanine transfer RNA (t RNA) from yeast : H.G. **Khorana & K.L. Agrawal.** In vitro synthesis of RNA. S. **Ochoa.**

One gene - one enzyme hypothesis was given by **Beadle & Tatum** in 1943 while working on biochemical mutant *Neorospora crassa* (fungus).

J.D. **Watson** & F.H.C. **Crick** (1953) : proposed a model of DNA comprising of two helically interwined chains tied together by hydrogen bonds, between the purines & pyrimidines. In 1962 Watson, Crick & Wilkins got a Nobel prize for their studies on the structure of DNA.

R.H. **Holley**, H.G. **Khorana** & M.W. **Nirenberg** got Nobel prize for deciphering the genetic code.

Paul Berg : Genetic Engineering. Two enzymes are used i.e (i) Endonuclease : Cuts the DNA (ii) Ligase : unites the broken DNA.

Plasmid : Circular DNA independent of chromosome.It is the vehicle that transfers DNA in genetic engineering. It is extra chromosomal DNA molecule.

How gene operates? i.e **operon concept** of gene was given by **Jacob & Monod.**

Modern concept of gene i.e gene fine structure was given by **Benzer**

According to the classical concept, the smallest unit for recombination, mutation & function was only gene. But Later on three terms have been coined by Benzer viz.

(a) **Recon** is the smallest unit for recombination. It consists of maximum of two pairs of nucleotides & may be only one.

(b) **Muton :** It is the smallest unit of mutation. An alternation in a single nucleotide pair can result in the mutation. Muton is the smallest in size.

(c) **Cistron :** It is the functional unit where hundreds of nucleotide pairs take part. It is the largest in size. Generally we use 'gene' instead of cistron.

One gene controls one character

One gene – one protein

One gene – one chain

One gene – one polypeptide

One cistron – one polypeptide

Barbara Mc Clintock worked on maize (1983) & found that Gene moves around genome i.e mobile genetic element.

Genome : is the haploid set of chromosome.Genes are located on chromosomes of haploid cell.

Allele/Allelomorph : are genes that occupy corresponding position on maternal & paternal chromosomes. Allelomorph means one form or the other i.e alternative forms of the same gene which is substitute for one another. Individual having only one allele (ie two identical alleles) is called homozygous (DD, dd, tt, TT)

Father of Genetics : Mendel

Father of Drosophila (fruit fly) genetics : T.H. Morgan.

Gynandromorph :

Gyn	+	andro	+	morph
↑		↑		↑
Female		Male		form
♀		♂		

means some part of body is female & other parts are male e.g. Drosophila.

Chromosome : Discovered by Strasburger and the term was given by Waldeyer.

In Prokaryota	:	Single chromosome & circular called Genophore (without histone).
In Eukaryota	:	Rod shaped chromosome.
Sex chromosome	:	Allosome/Idiosome : discovered by Mc Clung.

Chromosome
- Autosome
- Allosome/Heterosome/Sex Chromosome (X,Y)

Holandric genes are located on Y-chromosome responsible for maleness.

Centromere/Kinetomere is the driver of the chromosome i.e. movement of chromosome during cell division is controlled by centromere.

Linkage in plant : discovered by Bateson & Punnet (1906) worked on sweet pea *(Lathyrus odoratus)*.

Linkage in animal : discovered by T.H. Morgan worked on drosophila.

Sexuality : Reproductive parts of the plant

were firstly reported by N. Grew in 1682. **Sexual reproduction** in the plant was first time described by R. Camerarius in 1694. **Camerarius** also produced a hybrid between two different plant species for the first time. However in 1717. T. Fairchild produced a hybrid having characteristics of both parents popularly called 'Fair child's Sweet William' or '**Fairchild's mule**."

The mammalian egg was discovered by Von Baer in 1928.

History :

Earliest thought was that living organisms originated from non-living materials like decaying organic matter. That thought is known as **spontaneous generations.** This thought was supported by **Aristotle (384-322 BC)**.

Later on **Lois Pasteur (1822-1895)** and **Tyndall (1820-1893)** conclusively proved that organic matter decays due to presence of microbes in them and that microbes do not originate spontaneously from the organic matter.

According to **Swammerdam & Bonnet,** (1720-1793) A miniature human figure called 'homunculus' was already present in eggs/sperms and the development of progeny involved only the growth. This thought is called **Preformation.**

According to **Wolf (1738-1794)** : Neither the egg nor the sperm had a structure like homunculus but the gametes contained undifferentiated living substance capable of forming the organised body after fertilization. This thought is called **Theory of epigenesis.**

Jean Baptiste **Lamarck (1744-1829)** proposed that characters acquired by individuals of one generation are transmitted to those in the next generation. This thought of inheritance of acquired character was originally suggested by **Hippocrates** (400 B.C.). The proposal of Lamarck is known as **Lamarckism** or the **theory** of **Inheritance of Acquired characters.** Lamarck did not point out the physical basis of his theory. The theory of Lamarck was supported by **Charles Darwin (1809-1882)**. Darwin tried to suggest the **physical basis of heredity** and suggested that every part of body produced very small invisible bodies called 'gemmules' or

'pangenes' which are transported through the blood stream to the sex organs and are assembled there into gametes. During fertilization, gemmules from both parents are brought together for redistribution to different organs during development. In this way the different characters are determined. This is known as **Theory of Pangenesis.** It is almost a copy of Lamarck's therory except that Darwin suggested a physical basis. Darwin is known for '**Theory of Natural Selection** and his famous book **'Origin of species'.** According to theory of Natural selection :-

(a) Variation was constant in nature. He believed that continuous variation was the basis for evolution :

(b) Over production of offsprings brings a struggle for existence.

(c) Natural selection operates for survival of fittest & elimination of units.

(d) Heredity continues the line of survivors.

August Weismann (1834-1914) proved that theory of pangenesis was wrong. He conducted experiments on mice for 22 generation by cutting off the tails generation after generation. Although the complete tail structure was still inherited. He propounded the **germplasm theory :-**

(a) The body of an individual is divided into two types somatoplasm & germplasm. The hereditary material is separated into the germplasm at early stage of an individual while the rest of body (Somatoplasm) is only a house of the germplasm.

(b) Any change affecting the somatoplasm but not reaching to germplasm in not heritable.

(c) The somatoplasm dies with the death of an individual but the germplasm lives on. It is immortal.

The germplasm theory laid the foundation of modern genetical thought. However it was difficult to distinguish between germplasm & somatoplasm. It is now known that the chromosomes are the main carriers of hereditary characters.

Physical basis of heredity :

Mendel used the term 'Marmal' to designats the genetic factor during his experiment on Pea. Later on Johannsen's term 'gene' has been accepted as a unit for the basic genetic factor of heredity. The genes are located on the chromosomes in a linear order. The chromosome is the thread like structure present in the nucleus of the cell. Each species has a fix number of chromosomes. In each nucleus, there are two identical sets of chromosomes in which one set comes from the male parent and other from the female parent. The pair of corresponding chromosomes are called homologous chromosomes.

*

22 The Cell

Cell is the latin word means a little room. An English scientist, Robert Hooke, discovered the cell in 1665 while examining thin section of cork under his simple microscope. He obserbed a mass of empty hexagonal chambers like a honeycomb and called the compartment cells. Robert Hooke wrote the book 'Micrographia'.

A cell is the structural and functional unit of life and is defined as a mass of protoplasm bounded by a plasma membrane.

In 1838, a German botanist, Schleiden. and in 1839, a German zoologist, Schwann proved that the plants and animals are cellular in character and founded the cell theory. They postulated that the cell is the basic unit of all life. In 1885, Virchow proposed the idea that all cells arise from pre-existing cells.

In 1861, De Bary and Schultze put forward 'Protoplasm theory' means the cells (units of plants and animals) are tiny masses of protoplasm, each containing a nucleus. In 1884, Strasburger concluded that the nucleus is related to inheritance of characters. The size of majority of cells is 3-30 μ.

Smallest cell : PPLO; size : 0.1-0.5μ; PPLO means pleuro-pneumonia like organism.

Largest cell : Ostrich egg : size : 170mm $\times$ 135mm

Largest cell in human body : Nerve cell;

Size : 90μ in length.

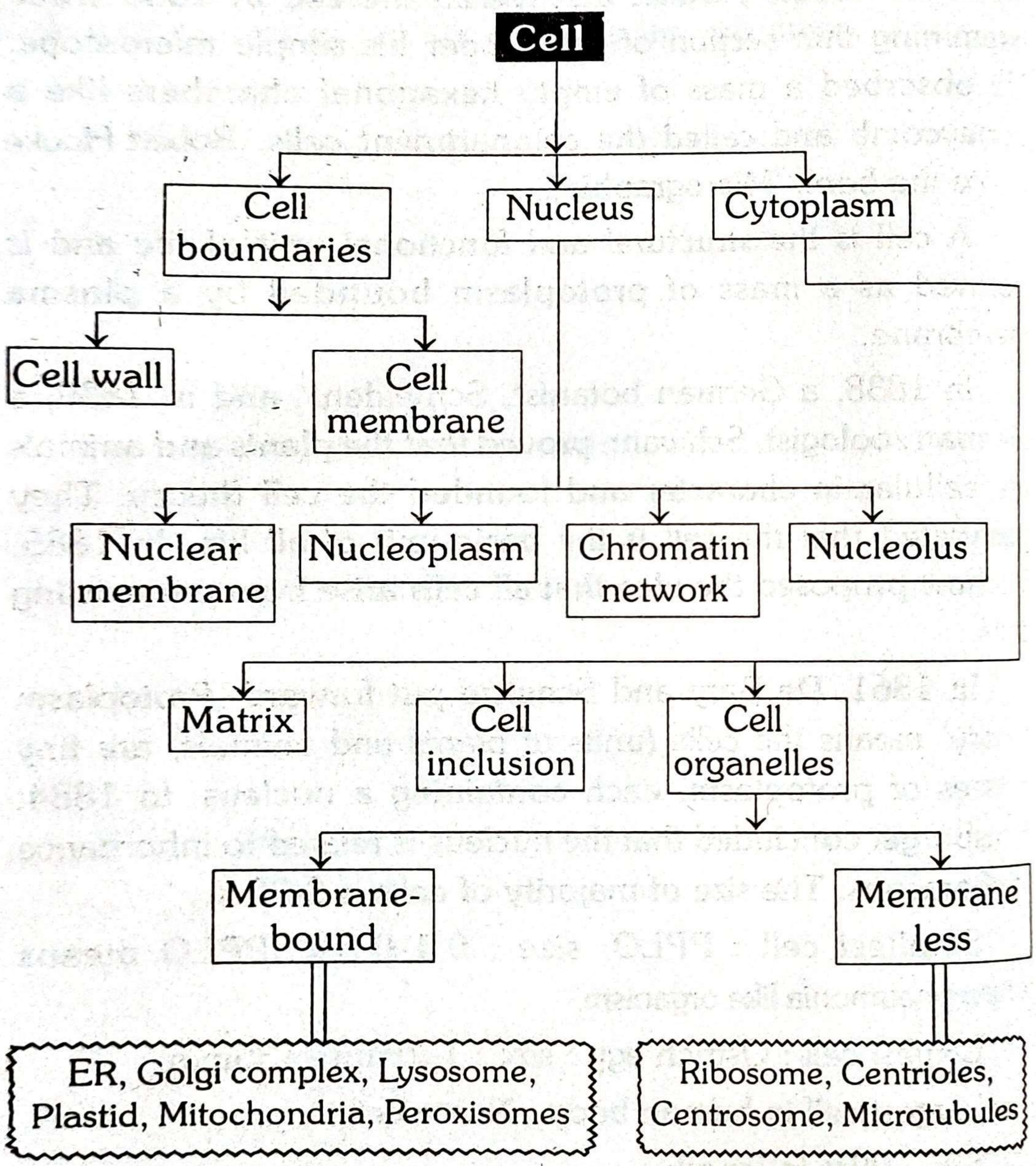
Resolving power of human eye : 100μ

" " " Light microscope : 3000 A^0or (0.3μ)

" " " Electron microscope : 0.25 A^0

($1\mu = 10^{-6}m$; $1A^0 = 10^{-10}m$)

Structurally the cell is formed of three parts viz.
(1) Cell boundaries, (2) Cytoplasm, (3) Nucleus



The Plant cell seen under Light microscope.

- Plant cell
  - Cell wall (non-living)
  - Protoplast or cytosome (living+non-living)
    - Protoplasm (living)
      - Nucleus
      - Cytoplasm
        - → Mitochondria (look like particle)
        - → Plastids (like particle)
        - → Hyaloplasm (clear substanee)
    - Ergastic substances (non-living cell inclusions)

Hyaloplasm under electron microscope

- → Plasma membrane
- → Endoplasmic Reticulum
  - Smooth
  - Rough (with Ribosome)
- → Dictyosomes (Golgi apparatus of plants)
- → Lysosomes
- → Spherosomes
- → Tonoplast (Vacuole)
- Plasmodesmata

Table : Differences between prokaryotic and eukaryotic cells

Feature	**Prokaryotic cell**	**Eukaryotic cell**
Cell size	Average diameter 0.5-5 μm	Diameter varies between .1 μm - 40 μm
Protoplasm	Relatively rigid, resistant to desiccation (drying) and can withstand	More fluid and sensitive to drying and to changes in temperature and

	wide changes in pressure and temperature	pressure
Nucleus	Lacks true nucleus; circular DNA lies naked in the cytoplasm; no chromosomes, nucleolus or nuclear membrane; nucleoplasm undifferentiated from cytoplasm	True nucleus bound by nuclear membrane contains linear DNA associated with proteins and RNA (forming chromosomes); nucleolus and nuclear membrane present; nucleoplasm distinct
Organelles	Membrane-bound organelles like Golgi bodies, plastids, mitochondria and endoplasmic reticulum (ER) are absent	Membrane-bound organelles present
Ribosomes	Smaller and randomly scattered in the cytoplasm	Bigger, can be free or attached to the ER
Cell division	Divides by simple fission; spindle is not formed; no mitosis and meiosis.	Divides by mitosis or by meiosis
Respiration	Respiratory enzymes are located on the plasma membrane	Mitochondria are the seat of aerobic respiration
Photosynthesis	No organized chloroplast;	Organized chloroplasts

	photosynthesis takes place on photosynthetic membranes which lie freely in the cytoplasm	(containing stacked membranes called grana) take part in photosynthesis
Examples	Bacteria and cyanobacteria (blue-green algae)	All other organisms

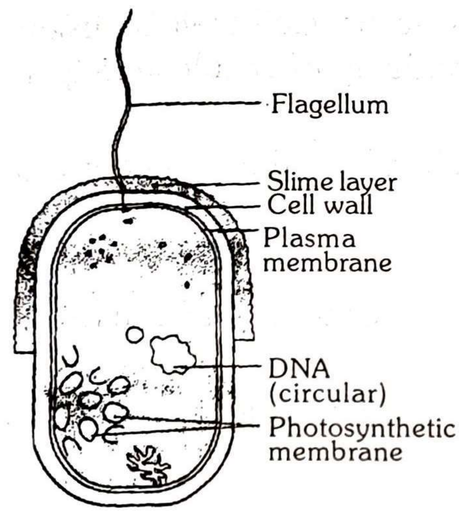


Fig. Prokaryotic cell (Bacteria)

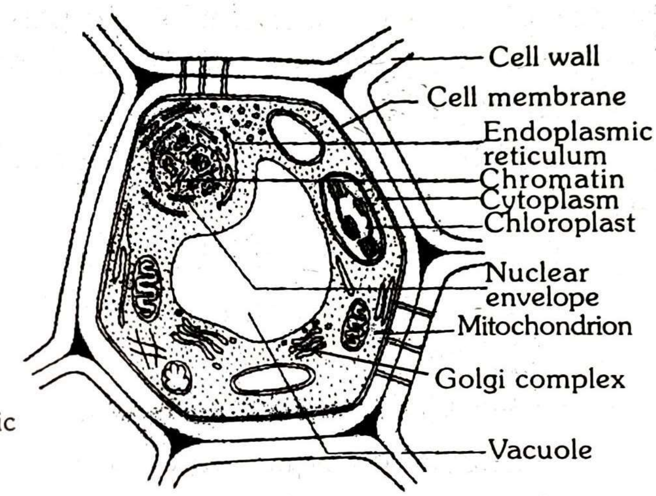
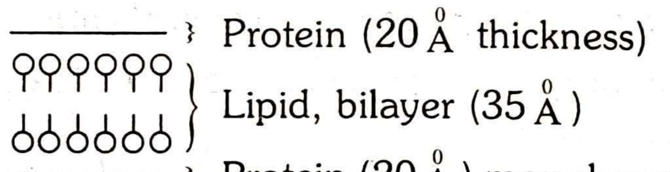


Fig. Eukaryotic plant cell

Plasma membrane/Cell membrane/plasmalemma :

It is the extremely delicate, thin, elastic and living membrane which surrounds a cell. In plant cell, it is present on the inner side of the cell wall. It is made up of two layers of lipid (fat) molecules (size 35 Å) with protein molecules (each 20 Å) sandwiching it and embedded in it. It is a lipo-protein membrane.



Total thickness of the membrane is 75 Å -100 Å

Plasma membrane is a selectively permeable (semi-permeable) membrane and its function is osmoregulation of molecules. It protects the internal structures and gives shape and rigidity to cell. In animal it is the outermost structure of the cell and hence called 'ectoplast'.

Plasma membrane is absent in virus.

Cell Wall : Plant cells have an additional protective wall outside the plasma membrane, called the cell wall.

Cell wall is the non-living and thick envelope and is the most important character of the plant cells. Cell wall is absent in animal cells. It is permeable and made up of cellulose (a type of carbohydrate).

Middle lamella joins primary cellwall of the adjacent cell walls.

Chemically (middle Lamella)

- → rich in pectin (cementing material and also used in jelly making)
- → Ca^{2+} (trace of Mg also) : provides rigidity.

Primary cell wall contains :-

- → Cellulose (Polymer of hexose (6c) glucose)
- → Hemicellulose (Polymer of mannose/galactose/ Pentose)
- → Pectin (hydrophilic)

Pectin is in primary cell wall in lower plants but in higher plants it is present in middle lamella.

Plant cell type on the basis of the **nature** of cell wall :

(a) Primary cell wall (callulose) present; secondary cell wall absent or very thin e.g. **Parenchyma.**

(b) Primary wall (cellulose) present + Secondary wall (cellulose only) also present e.g. **collenchyma.**

Mechanical property of collenchyma is due to cellulose in its secondary wall.

(c) Primary wall present+Sec. wall thick (cellulose+lignin) e.g. **Sclerenchyma,** vessels, Tracheids

Lignin : chemically it is coniferyl alcohol and solid at room temperature. It gives mechanical strength.

Plant cell type on the basis of lignin :

(a) non-lignified cells (lignin absent) e.g. parenchyma, Collenchyma, Sieve tubes.

(b) Lignified cells (Lignin present) : e.g. Sclerenchyma, vessels & tracheids. Classroom stain for lignified cells : Safranin.

Protoplasm :

All the components of a cell including the cell membrane is called protoplasm.

It is the living part of the cell.

The term 'protoplasm' was given by J.E. Purkinje (1830-37). Plasm means substance.

According to Huxley : Protoplasm is the physical basis of life. 80-90% of protoplasm is water.

Protoplasm is colloidal in nature and heterogenous. In dry protoplasm, protein is the most abundant constituent (60-70%).

Nucleus :

Discovery of nucleus : Robert Brown (1833).

The nucleus is surrounded by a double membrane nuclear envelope (having pores) called nuclear membrane which is chemically lipo-protein.

The size of nuclei : 5 - 25 μ

A true nucleus is absent in bacteria and blue-green algae (cyanobacteria) but nuclear materials are present in them.

Nucleus is absent in matured mammalian RBCs and in the sieve tube cells in phloem.

Inside the nuclear membrane. there is a colourless dense sap called **nuclear sap, karyolymph** or **nucleoplasm or Karyofluid.**

Inside the nucleoplasm. a tangled mass of threadlike structures is called **chromatin.**

Chromatin : made up of DNA + Protein.

DNA : Deoxyribonucleic acid

When chromatin condense into rod like bodies during cell division called chromosomes.

Chromosome contains stretches of DNA. DNA carry information for protein synthesis. The stretches of DNA are called genes. Genes are passed from parents to the progeny. Hence gene is called hereditary unit and DNA is called hereditary material. Genes control the production of enzymes which guide metabolic activities.

Nucleolus :

A spheroidal and densest organelle in the nucleus is nucleolus.

Nucleolus contains DNA which synthesizes ribosomal RNA (Ribonucleic acid)

It is discovered by Fontana (1781). It is rich in RNA but also contains DNA.

The main function of nucleolus is to synthesize Ribosomal RNA (r RNA).

It is attached to the specific site of chromosome which is called 'nucleolar organiser'.

In eukaryotes, at least 3 RNA polymerases are present in nucleus viz.

(i) RNA Polymerase I or A : located in nucleolus, responsible for r RNA synthesis

(ii) RNA Polymerase II or B : found in nucleoplasm, responsible for Hn RNA synthesis (Heterogenous nuclear RNA)

(iii) RNA Polymerase III or C : found in nucleoplasm, responsible for synthesis of sRNA & tRNAs.

Chromosome :

Chromosome was first seen by Strasburger in 1875 as fine thread. But the name 'Chromosome' (Chroma=colour + soma = body) was first used by Waldeyer in 1888 using basic dye.

Chromosomes are the carriers of hereditary units i.e genes.

In all the species, there is a certain no. of chromosomes viz. in human 2n = 46, in rice 2n = 24. In Prokaryotes, there is a single chromosome which is circular in shape and is called

genophore (without histone) whereas in eukaryotes chromosomes are rod shaped.

$$\text{Chromatin} \xrightarrow{\text{Chemically}} \text{nucleo protein}$$

- Nucleic acid
  - DNA
  - RNA
- Protein
  - Histones
  - Non-histones

Nucleic acid is the polymer of nucleotides.

One nucleotide = Sugar + Nitrogenous base + Phosphate (H_3PO_4)

One Nucleoside = Sugar + base only

Nucleotide = Nucleoside + Phosphoric acid

Nitrogenous bases are :

A → Adenine G → Guanine

T → Thymine U → Uracil

C → Cytosine

Such bases are ring structured.

Purines : two rings e.g. A,G

Pyrimidines : Single ring e.g T, U, C.

DNA model : Watson & Crick (1953)

book : Double Helix

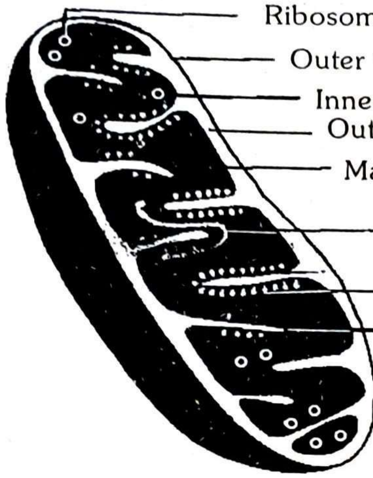
Wilkins : X-ray diffraction of DNA.

Mitochondria : 'Power house of cell'.

Energy is generated as~ATP (~means energy). ATP is known as 'Energy currency'.

Mitochondria was firstly identified by Altman in 1886 as 'Bioplast' and suggested their association with respiration.

The term 'mitochondria has been given by C. Benda (1898). It was first observed by Kolliker (1853).



Mitochondria is the site of aerobic respiration or krebs cycle

Site of glycolysis : Hyaloplasm (not cytoplasm)

Electron transport : Oxysome/F_1 particle/Elementary particle. Enzymes confined in Perimitochondrial space and reactions on inner membrane.

Mitochondria contain DNA, RNA (0.02% DNA, 3-4% RNA) & ribosomes. Hence called 'semi-autonomous' body of the cell because of capability of some protein synthesis.

Plastids :

According to Schimper (1885)

(a) Green coloured plastids are called chloroplasts.

(b) Red, Yellow, Brown, Orange → Chromoplast (chromo means coloured)

(c) Colourless : Leucoplasts . The main Function of leucoplasts is food storage.

Leucoplast
- → Amyloplast : Storage of starch
- → Elaioplast : " " Oils
- → Aleuronoplast : " " Protein
  or Proteinoplast

Chroloplast : pigment chlorophyll

chlorophyll

- → Chlorophyll a : blue black, $C_{55}H_{72}O_5N_4Mg$
- → Chlorophyll b : Green black, $C_{55}H_{70}O_6N_4Mg$
- → Carotene : yellowish Orange, $C_{40}H_{56}$
- → Xanthophyll : Yellow, $C_{40}H_{56}O_2$

Chl.a & chl. b in green plants : 65%

Carotene → red, 6%

Xanthophyll → yellow 29%

Carotene & Xanthophyll are together called carotenoid pigment.

In chromoplast, only carotenoid pigments are found.

Plant pigments

- → Plastid pigments e.g. chlorophyll, carotenoids, such pigments are soluble in organic solutions only. Found in leaves & skin of fruits.
- → Sap pigments : Solution of salts & sugars. found in vacuoles e.g. Anthocyanins (soluble in water). found in flower petals & beets.

Chloroplasts :

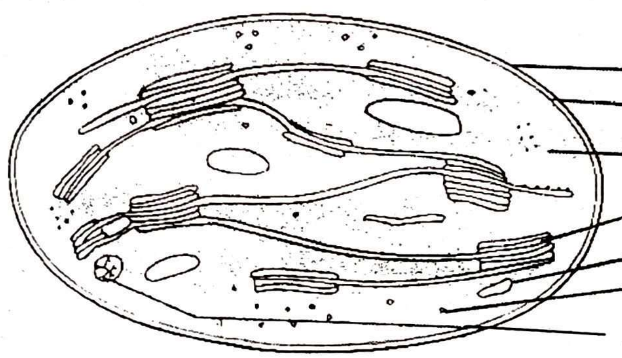


Fig. Internal structure of a chloroplast (green plastid)

Grana lamellae :

$$\text{Thylacoids} \longrightarrow \text{Quantasomes} \xrightarrow{\text{contain}} \text{pigment}$$

lamellae means membranous tubes

site of Light reaction : Grana/thylacoids/quantasomes

" " Dark " : Stroma/matrix

Chloroplast contains DNA (0.5%), RNA (3-4%) and ribosomes. Therefore chloroplast is capable of some independent protein synthesis hence called semi-autonomous body of the cell. A plastid has two distinct regions viz **grana** & **stroma.**

Grana are stacks of membrane bound, flattened, discoid sacs containing chlorophyll molecules. Such molecules are responsible for the food production, hence called the **kitchen of the cell.**

The homogenous matrix in which grana are embedded is known as stroma.

Endoplasmic Reticulum (ER)

Endoplasmic Reticulum is a dense network of double membraned (unit membrane) structures running through the cytoplasm. It may be continuous; some parts are connected to the nuclear membrane while others are connected to the plasma membrane especially in animals.

Its origin is from nuclear membranes. Ultrastructure of ER was first reported by Porter (1948).

It is not a stable structure. It is capable of being broken down and reconstructed. It undergoes partial fragmentation at the time of cell division.

Two types of ER:

→ Rough ER (RER) : When ribosomes are attached on it.

→ Smooth ER (SER) : No ribosomes are attached on its surface

Function :

(1) ER forms endoskelton to provide a particular shape to the cell (mechanical support), especially in animals.

(2) Membranes of ER provide the surface for the increased metabolic reaction.

(3) Intracellular transport of metabolic products or molecules (eg protein).

(4) It helps in the formation of cell plate and nuclear membrane during cell division.

(5) Synthesis of protein on ribosomes means Rough ER is associated with the protein synthesis.

(6) Smooth ER (SER) secretes lipids which along with proteins constitute cell membrane by a process called membrane biogenesis.

(7) Transmission of impulses in animals.

(8) SER plays a crucial role in detoxifying many poisons & drugs.

Ribosomes/RNA particles :

r RNA (ribosomal RNA) 60-40%	Protein 40-60%

RNA

genetic RNA	non-genetic RNA

First observed by Claude (1943) but reported as 'microsomes' (ER fragments + ribosomes). Palade (1956) isolated the ribosomes and reported their detailed ultra structure.The term 'ribosomes' by R.B. Robert (1958)

Types of RNA (non-genetic)

- → m RNA (messenger) : 5-10% of total RNA
- → t RNA (transfer) / soluble RNA (sRNA) 10-15% of total RNA, Smallest in size. Clover leaf model.

} directly take part in protein synthesis.

- → r RNA : provides site for protein synthesis. 80% of total RNA, Most stable RNA.

Two major steps are involved in protein synthesis :

(i) transcription i.e. transfer of genetic information from DNA to mRNA

(ii) translation i.e. translation of the language of nucleic acids into that of proteins.

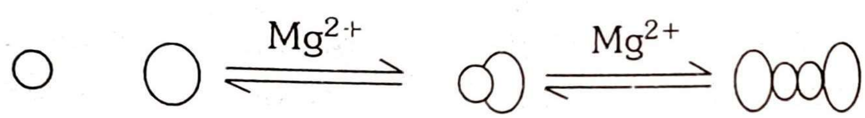
$$\text{DNA} \xrightarrow{\text{transcription}} \text{mRNA} \xrightarrow{\text{translation}} \text{Protein}$$

Fig : One way tlow of infomation (Central dogma)

A ribosome has two subunits, one is smaller and other is bigger. In bacterial cells & chloroplasts of higher plants, sedimentation coefficient (S) of complete ribosome is 70 S which has subunits 30 S and 50 S.

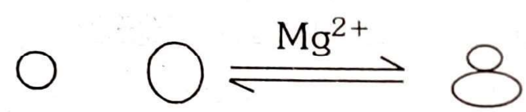
In higher organisms sedimentation coefficient of ribosomes is 80 S which has subunits 40 S & 60 S. Higher concentration of Mg^{++} ion promotes association of subunits into complete ribosome.

Lower concentration of Mg^{2+} dissociates these subunits.



40 S 60 S 80 S 120 S

Subunits of ribosome in hihger plants — ribosome (Eukaryotic) — dimer



30 S 50 S 70 S (prokaryotic ribosome)

Subunits of ribosome in bacteria

There is no lipid content in ribosomes.

Golgibody/Dictyosome

discovered by Camillo Golgi (1898). Golgi complex or bodies are formed by stacks of flattened (saucer-shaped) membranes. Flattened sacks are called **cisternae.** Golgi bodies are usually called dictyosomes in plants.

It's origin : from ER.

'Acrosomes' are associated with Golgi complex

Functions :

(1) They store, modify, package and condense the protein synthesized in the ribosomes.

(2) They form the cell plate during cell division.

(3) They add sugars to some proteins and synthesize some polysachharides for the cell membrane.

(4) They set aside digestive enzymes in tiny membrane bound vesicles which become '**lysosomes**'.

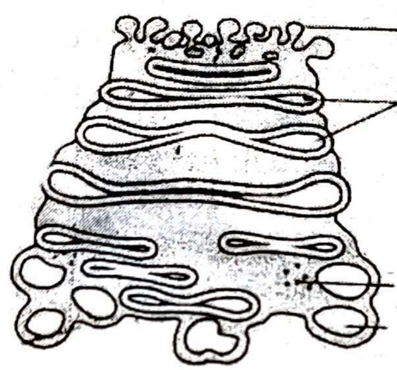


Fig. Structure of Golgi complex

Lysosome :

lysis means digestion; Soma means body

The saclike, small, spherical, single membrane bound vesicles containing digestive enzymes are called lysosomes.

These enzymes are synthesized in RER which are brought to the 'Golgi Complex.

Lysosomes are formed directly from Golgi complex & indirectly from ER.

Lysosomes are discovered by De Duve (1955); mainly found in animals but also is some plants like Neurospora. In animals, epithelial cells of the intestine, kidney cells rich in lysosomes.

Functions :

(1) Intracellular digestion. They help in breaking down (digesting) large molecules of cell.

(2) They work in defence against bacteria & virus.

(3) During starvation, lysosomes act on their own cellular organelles & digest them. This result in cell death hence are called 'suicidal bag' or demolition squads means cell autolysis or autophagy.

Spherosomes :

Single membrane bounded mainly in plants. It's function is fat metabolism.

Tonoplast (Vacuole) :

Important structure in plant cell. They may occupy upto 90% of the cell volume. Single membrane bound and contain cell sap. function osmo-regulation of molecules.

Plasmodesmata :

Found in plants only. First observed and named by Strasburger (1903).

In the form of cytoplasmic strands that connects the protoplast of adjacent cell.

Origin : from ER

Function : provide metabolic contacts between cells e.g. companion cells.

Centrosome :

Present near nucleus,present in all animal cells and also in chlamydomonas, some fungi, Gymnosperms etc. Two centrioles in one centrosome. At the time of mitosis, move to opposite pole and produce astral rays.

Ergastic Substances :

Non-living cell inclusions e.g. starch, sugar, organic acid, fats, oils, pigments etc.

Genetic material :

DNA & RNA are chemically called nucleic acids. Nucleic acids were first isolated by Miescher (1868) from the nuclei of white blood cells (WBC) of pus.

Table : Four nitrogen bases, nucleosides & nucleotides of DNA and RNA molecule.

DNA molecule :

Nitrogen base	Base + deoxyribose = deoxyribonucleoside	Deoxy ribonucleoside + phosphoric acid = deoxyribonucleotide	Abbreviation for nucleotide
Adenenine (A)	Deoxyadenosine	Deoxyadenylic acid (Deoxyadenosine monophosphate)	d AMP
Guanine (G)	Deoxyguanosine	Deoxy guanylic acid (Deoxyguanosine monophosphate)	d GMP
Cytosine (C)	Deoxycytidine	Deoxycytidilic acid (Deoxycytidine mo nophosphate)	d CMP
Thymin (T)	Thiamidine	Thymidylic acid (Thymidine monophosphate)	TMP

RNA molecule :

Base	Ribonucleoside	Ribonucleotide	Abbreviation for ribonucleo tide
Adenine (A)	Adenosine	Adenylic acid (Adenosine **monophosphate** (MP)	AMP
Guanine (G)	Guanosine	Guanylic acid (Guanosine MP)	GMP
Cytosine (C)	Cytidine	Cytidilic acid (Cytidine MP)	CMP
Uracil (U)	Uridine	Uridylic acid (uridine MP)	UMP

Structure of DNA :

According to J.D. Watson & F.H.C. Crick (1953) :

DNA molecule has two polynucleotide chains which are wrapped helically around each other in such a way that sugar-phosphate chain is on the outside and purine (A,G) & pyrimidines (C,T.) on the inside of the helix.

E. Chargaff & et. al observed that :

'The concentration of thymine was always equal to the concentration of adenine and the conc. of cytosine was always equal to the conc. of guanine.'

The total conc. of pyrimidines (T+C) was always equal to the total conc. of Purines (A+G) but the ratio of $\frac{A+T}{C+G}$ was found to vary widely in DNAs of different species.

The two polynucleotide strands are held together by hydrogen bonds between specific pairs of purines & pyrimidines.

Adenine is always paired with thymine by two hydrogen bonds and guanine is always paired with cytosine by three H-bonds.

$A = T$
$T = A$
$C \equiv G$
$G \equiv C$

The resulting stacked base-pairs in the two chains are perpendicular to the axis of the molecule like the steps of a spiral staircase.

The base pairs are stacked 3.4 $\overset{0}{A}$ apart with 10 base pairs per turn (360°) of the double helix.

Once the sequence of bases in one strand is known, the sequence of bases in the other strand is also known because of the specific base-pairing. The two strands are thus said to be complementary i.e not identical. means the sequence of nucleotides in one chain dictates the sequence of nucleotides in the other.

The two strands run anti-parallely i.e have opposite directions.

Both polynucleotides strands are separated by 20 $\overset{0}{A}$ distance.

Structure of RNA :

RNA is either single stranded or double stranded but not helical like DNA.

In most plant viruses, genetic material is RNA. In many bacteriophages, genetic material is RNA.

Virus	Type of RNA
Plant Viruses	
Turnip yellow mosaic virus (TYMC)	Single stranded
Wound tumour	Double stranded
Animal viruses	
Influenza virus	Single stranded
Rous Sarcoma	Single stranded
Poliomyelitis	Single stranded
Reovirus	Double stranded
Bacteriophages	
MS 2, F 2, r 17	Single stranded

When RNA is double stranded, it generally follows the same rules of base pairing as in case of DNA.

The non-genetic RNAs except t RNA (of prokaryotes & eukaryotes) also have single stranded. t RNA (s RNA is soluble and non-genetic) is double stranded but non-helical.

Each strand of RNA is polynucleotide. RNA is the genetic material where organisms have only RNA (not DNA) but organisms which have DNA along with RNA, use of the RNA is carrying the orders of DNA and in this way RNA has no genetic role so called non-genetic RNA. Non genetic RNA is synthesized on DNA template. Non genetic RNAs are m RNA, t RNA & r RNA.

Genetic RNA of viruses is self replicating i.e it can produce its own replica by itself. So its model of replication is called RNA-dependent RNA synthesis.

Table : Comparison between DNA and RNA

Characteristic	DNA	RNA
Pentose	Deoxyribose	Ribose
Base	Thymine present and uracil absent	Ordinarily, uracil present and thymine absent.
Number of strands	Generally double-stranded	Generally single stranded
Function	1. Genetic material only	1. Generally nongenetic functions, e.g. mRNA rRNA, tRNA and chromosomal RNA.
	2. Generally in all organism it serves as genetic material	2. In some viruses, It serves as genetic material.
Origin	1. Replication of pre existing DNA.	1. Genetic RNA either through transcription of DNA or DNA
	2. In case of infection by RNA viruses, reverse transcription of genetic RNA	2. Through replication of RNA by RNA dependent RNA polymerase. 3. Nongenetic RNA from transcription of DNA
Native form	Double stranded DNA usually in B-form.	Double-stranded RNA usually in A-form.

Genetic Code :

DNA molecule is the carrier of genetic informations. These informations are in the form of certain special language of code words which utilizes the four nitrogen bases (e.g. ATC & G) of DNA for its symbols. Such coded message is called cryptogram.

Nucleic acids govern the protein synthesis. Proteins have 20 different amino acids but nucleic acid has only 4 different bases. It means 20 amino acids are the alphabets of the language of Proteins but 4 bases are the alphabets of the language of

nucleic acids. Genetic informations are passed on to the protein synthesis through mRNA.

Since 20 amino acids are to be coded, triplet code of bases gives $4 \times 4 \times 4 = 64$ codons which are enough. Out of 64 triplets, 44 triplets are excess which show that more than one codon are present for the same amino acids.

Primary structure of protein is amino acids. These essential amino acids are 20 in number viz-

1.	alanine	11.	Isoleucine
2.	arginine	12.	lysine
3.	asparagine	13.	methionine
4.	aspartic acid	14.	phenylalanine
5.	cystein	15.	proline
6.	glutamic acid	16.	serine
7.	glutamine	17.	threonine
8.	glycine	18.	tryptophan
9.	histidine	19.	tyrosine
10.	leucine	20.	valine.

Characteristics of triplet code

1) The code is triplet : Singlet and doublet codes are not enough to code for 20 amino acids. Triplet code is the minimum requirement.

2) The code is degenerate : In triplet code for a particular amino acid more than one word (synonyms) can be used. This is called degenerate code but in a non-degenerate code there would be one to one relationship between amino acids and the codons. So that 44 codons out of 64, will be useless codons e.g. 3 amino acids-arginine, serine & leucine-each has six synonymous codons. All codons starting with CC specify proline (CCU, CCC, CCA & CCG).

3) The code is non-overlapping means a base in a mRNA is not used for two different codons. The same base can not be used for two different codons for synthesis of the same

amino acid. The same base can be used for different codons only at different occasions in time and or space.

4) The code is commaless. No codon is reserved for punctuation. After the coding of the one amino acid, the second amino acid is automatically coded by the next three letters.

5) The code is ambiguous means the same codon may specify more than one amino acid. e.g. UUU codon usually code for phenylalanine but in presence of streptomycin, may also code for isoleucine, leucine or serine.

6) The code is universal i.e the same code applies in all kinds of living systems.

7) Starting codons : AUG codon is called starting or chain initiation codon which initiates the synthesis of polypeptide chain.

8) Non-sense codons : The UAA, UAG & UGA codons do not specify any amino acid. Therefore these codons are called non-sense codons or termination codons. Termination codons terminate the translation of a particular polypeptide.

23 Cell Division

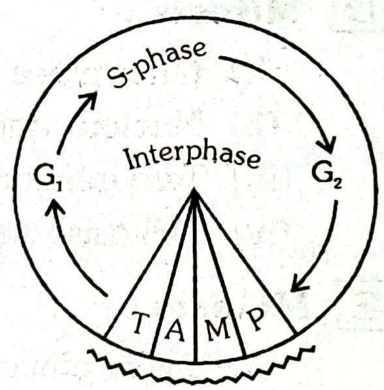
Cell is the functional and structural unit of living organism. Cell is the basic unit of life. All the cell originates by cell division in existing cell. The division of chromosomes and cytoplasm of a cell into daughter cells is called cell division.

Karyokinesis : Means Division of Nucleus

Cytokinesis : Means Division of cytoplasm

Cell division cycle :

S-phase : Synthesis phase



(i) Synthesis of DNA/ Replication of DNA/Doubling of DNA occurs.

(ii) DNA doubles at Interphase of mitosis & Pre-meiotic interphase.

G : Means gap

G_1 : Synthesis of RNA & Protein. It is pre DNA phase. It is resting phase.

G_2 : Post DNA synthesis phase. Here planning of cell division occurs.

Metabolically the most active stage is Inter phase.

Karyokinesis takes less than one hour in most of the cases.

There are five types of cell division :

A Amitosis means chromosome does not appear and cell divides directly i.e. direct nuclear division e.g. Fission (bacteria), budding (yeast)

no Thread or Chromosome

[B] Endomitosis or C-mitosis

$\uparrow$

Colchicine

Chromosome doubling is not followed by cell plate formation.

Colchicine is a chemical which stops the spindle fibre formation & induces polypoidy.

Colchicine is obtained from *Colchicum luteum* (family liliaceae)

[C] **Brachymeiosis :** Nucleus divides thrice. First and third division are reductional and 2nd is mitosis. discovered by Claussen e.g. Ascospores formation in Ascomycetes.

[D] **Mitosis :**

(i) takes place in both vegetative and reproductve cells.
(ii) Nucleus and cytoplasm divide once.
(iii) Two genetically identical cells are formed.
(iv) "Mitosis" was used firstly by Walter Flemming in 1882.

[E] **Meiosis :**

(i) Takes place in reproductive cells.
(ii) Nucleus and Cytoplasm divide twice.
(iii) 4 genetically but not identical cells are formed.
(iv) Meiosis means separation of chromosomes in sex cells.
(v) Chromosomes split longitudinally only once.
(vi) Chromosome number is reduced to half.
(vii) Discovered by Strasburger.
(viii) The term 'meiosis' (reductional division) was given by Farmer & Moore.

* **Neurospora :** Used in genetic studies because

(a) All the products of meiosis are within the same sac.
(b) Neurospora has a short life cycle.

* **Asynapsis** : Not allow to pair with homologous chromosomes and remain unpaired due to presence of gene.
* **Desynapsis** : Chromosomes actually paired during diakinesis, chiasma falling apart due to presence of genes.

Mitosis

Karyokinesis : It has four major stages :

A Prophase :

(1) Prominent nucleolus & Nucleus.
(2) Chromonemata formation; Thin, long and coiled chromosome.
(3) Each chromosome has two chromatid.

B Metaphase :

(1) Best stage for the study of chromosome.
(2) Nuclear membrane and Nucleolus are absent.
(3) Chromosomes appear as most condensed rod like structure.
(4) Chromosomes are arranged at equator i.e. centre of the cell.
(5) Thickest, smallest and clearest Chromosomes.
(6) Centromere exactly on the equatorial line.
(7) Spindle fibres are attached to kinetochore of centromere. Centromere is connected by spindle fibre on both the sides.

C Anaphase :

(1) Nuclear Membrane and Nucleolus are absent.
(2) Centromere divides and comes in 'V'-shaped.
(3) Chromatids move to their poles.
(4) Longitudinal splitting of centromere.

D Telophase :

(1) Nuclear membrane and Nucleolus reappear.
(2) Chromosomes uncoil.

Karyokinesis is followed by cytokinesis. In plant cells, the cytokinesis is through the formation of cell plate whereas in aninal cells, it is through the formation of cleavage furrow.

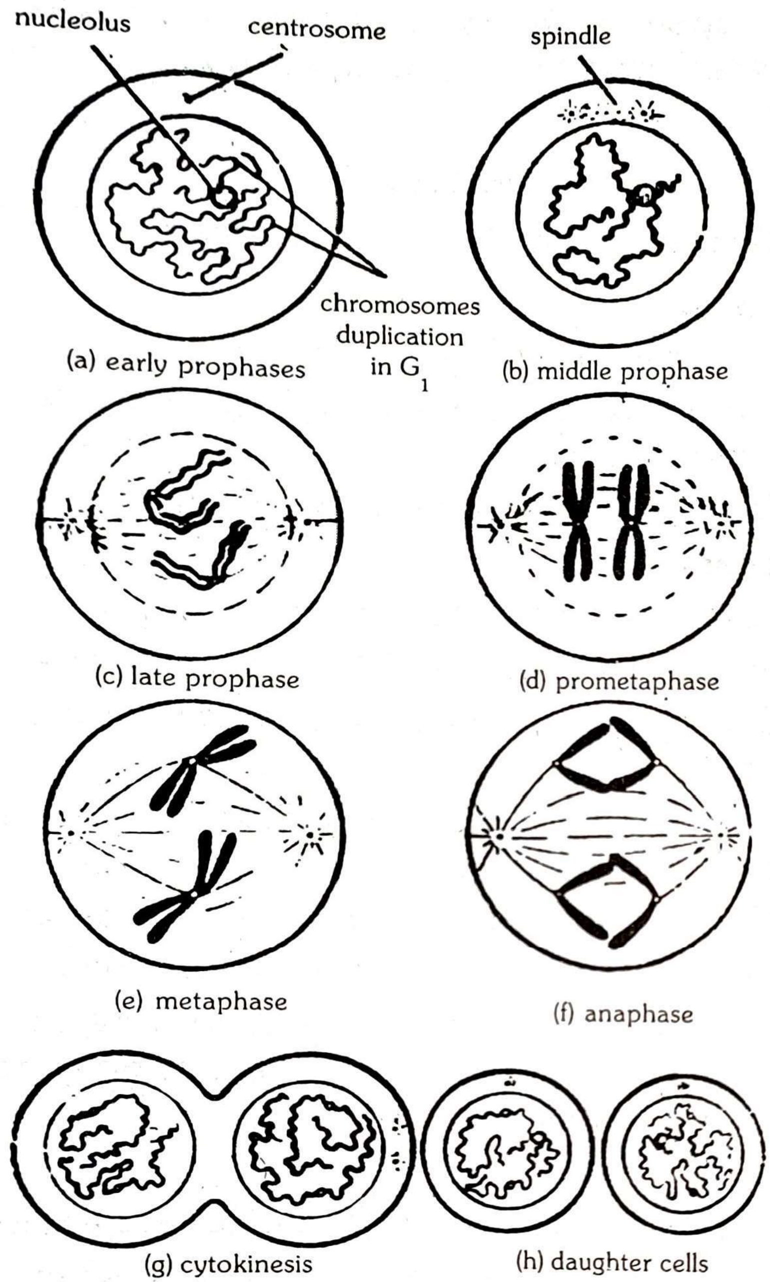


Fig. Various stages of mitosis in a somatic cell.

Meiosis

Meiosis has two successive divisions (viz meiosis I and meiosis II) with a short interphase in between them. Before undergoing meiosis I during the interphase genetic materials are duplicated due to active DNA replication.

Meiosis

- Karyokinesis I (Meiosis I) : Reductional division. It produces two haploid cells from a single diploid cell.
- Interphase (Interkinesis) : No Duplication of DNA, short period.
- Karyokinesis II (Meiosis II) : Equational division/simple mitosis.

Karyokinesis I/Meiosis I : It has a long prophase, metaphase, anaphase and telophase.

1 Prophase I :

Prophase I is of longer duration than the mitotic prophase and most of the cytogenetical events such as synapsis, crossing over etc. take place during this prophase. It is the longest stage and has five distinct phases.

(a) Leptotene / Leptonema / Bouquet stage

Lepto	tene	Lepto	nema
↕ means	↕ means	↕ means	↕
Thin	Thread	Thin	Thread

* Each chromosome is longitudinally single with a large number of chromomeres. Chromomeres are the beads on the chromosome. Chromomeres are discovered by Balbiani.

* Chromosome appears as long thin (lepto) thread like structure hence the name leptotene or leptonema.

* In some cells chromosomes appear and look like a bouquet hence the name Bouquet stage.

* A definite type of orientation and polarization of chromosomes towards the centrioles takes place.

(b) Zygotene/Zygonema/stage of synapsis or syndesis.

Zygo ↓ means

Coupled yoked

* Pairing of homologous chromosomes (i.e. synapsis/syndesis) takes place.

* Each pair of homologous chromosomes is called **bivalent.** Bivalent is formed as a result of synapsis. If pairing takes place from terminal region, it is called polarization.
* Synaptonemal complex appears and controls pairing. Synaptonemal complex is in between two homologous chromosomes (one is maternal and other is paternal chromosome) and discovered by Mosses at zygotene.
* Nuclear Membrane and Nucleolus are present.

(c) Pachytene/Pachynema :

$\downarrow$ means

Thick

* Longitudinal splitting of paired chromonemata along the length of chromonemata. The coiled filament of the chromosome which bears genes is called chromonema (chromonemata are plural) but there is no splitting of centromere.
* Splitting of chromonemata into chromatids takes place and bivalent has four chromatids.

Chromatid + its own centromere = chromosome. As a result **Tetrad** stage (4 chromatids) of homologous chromosomes is found. Dehydration and condensation of chromosomes occurs.

* The exchange of chromosomal or genetic material between non-sister chromatids of each tetrad takes place. Such exchange of genetic materials between non-sister chromatids is called **crossing over** which is the cause of hereditary variations.
* The point of crossing over (inter change) is called chiasma (plural-chiasmata) which is visible as characteristic X-shaped configuration.
* Crossing over leads to recombination of genes.
* Stern and Hotta (1969) reported that **endonuclease** enzyme breaks the chromatid and **ligase** enzyme unites the broken non-sister chromatids.
* A small amount of DNA is synthesised to repair the broken chromatids.

* % of crossing over helps in the preparation of genetic map or chromosome map. The unit of genetic map is centimorgan. 1 centimorgan means 1% crossing over. First genetic map was prepared by Sturtevant (of drosophila). Drosophila is the queen of genetics.
* Nuclear membrane and Nucleolus are present.

(d) Diplotene/Diplonema :

Diplo ↓ Means double

* Repulsion between homologous chromosomes begins.
* Terminalization of chiasma starts.
* Synaptonemal complex disappears.
* Nuclear membrane and Nucleolus present.

(e) Diakinesis :

* It is the end of both diplotene and prophase I.
* Terminalization is the characteristic feature.
* At the end, Nuclear membrane and nucleolus disappear.
* It is the best substage for counting the no. of bivalents.

2 Metaphase I :

* Nuclear Membrane and Nucleolus are absent.
* Bivalents are at equator. Chromosomes are exactly in equatorial plane but not necessarily centromere.
* Chiasmata are completely terminalized means absent.
* Spindle fibre is connected with centromere only at one side.

3 Anaphase I :

* Centromere does not divide means no separation of centromere; no splitting of centromere.
* Spindle fibre is connected with centromere at one side only.
* V-shaped chromosomes move to their poles.
* Reduction in number of chromosomes i.e. n of 2n.
* Nuclear membrane and nucleolus are absent.
* A tetrad is separated into diad and each diad has only one pair of chromatids.

* Here is simply separation of chromosomes.

* Every nucleus is in n-phase (half no. of chromosomes)

4 **Telophase I :**

* Chromosomes reached to the respective pole.

* Formation of nuclear membrane and nucleolus after some period.

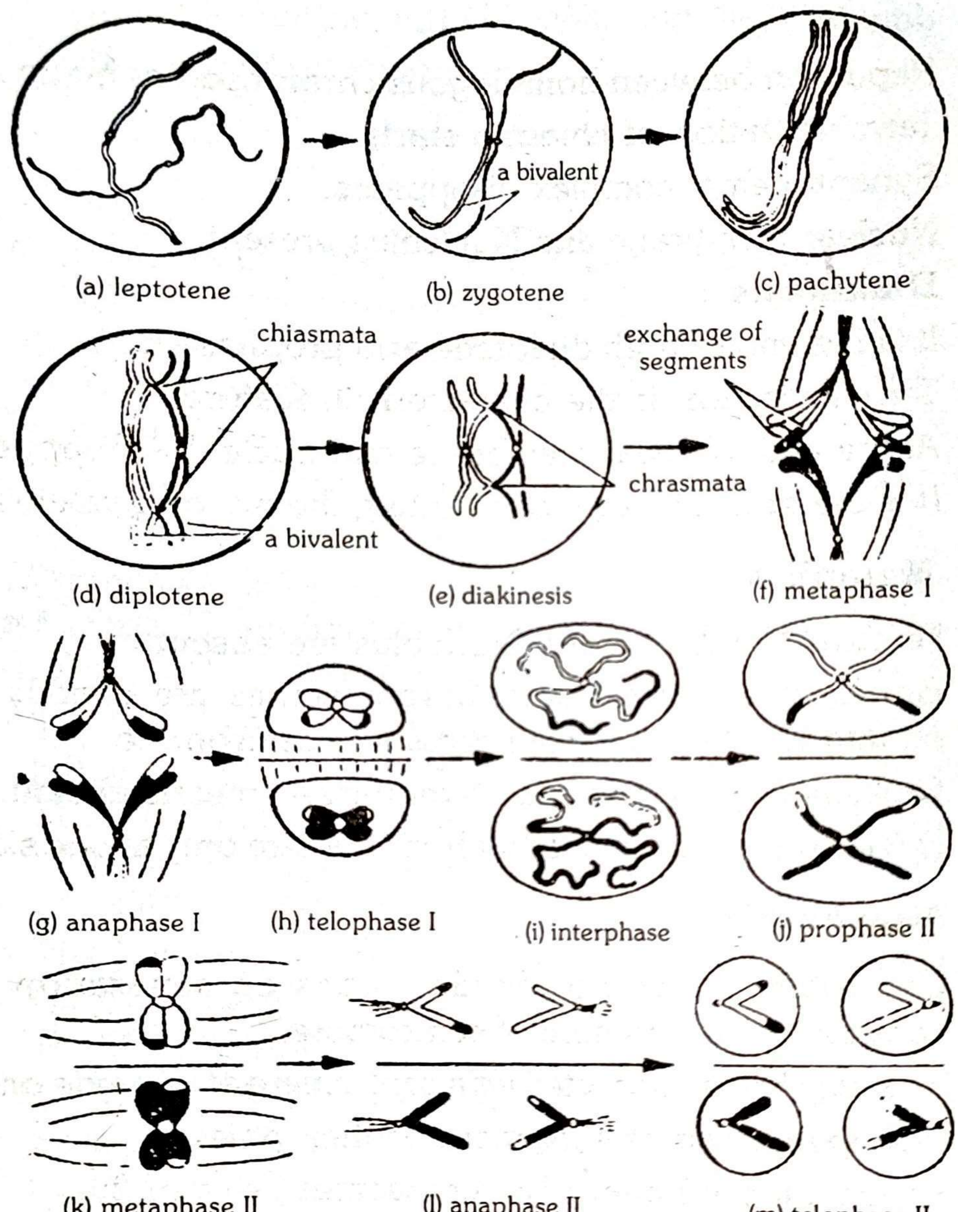


Fig. Various stages of meiosis in a mother cell, (for clearity, chromosomes at different stages are not shown in their relative sizes).

* 2 daughter nuclei are formed.

Interkinesis : Nuclear membrane and nucleolus become prominent. No duplication of DNA.

Meiosis II (simple mitosis) :

There is no prophase II. After certain period all the chromosomes lie on the equatorial plane immediately forming

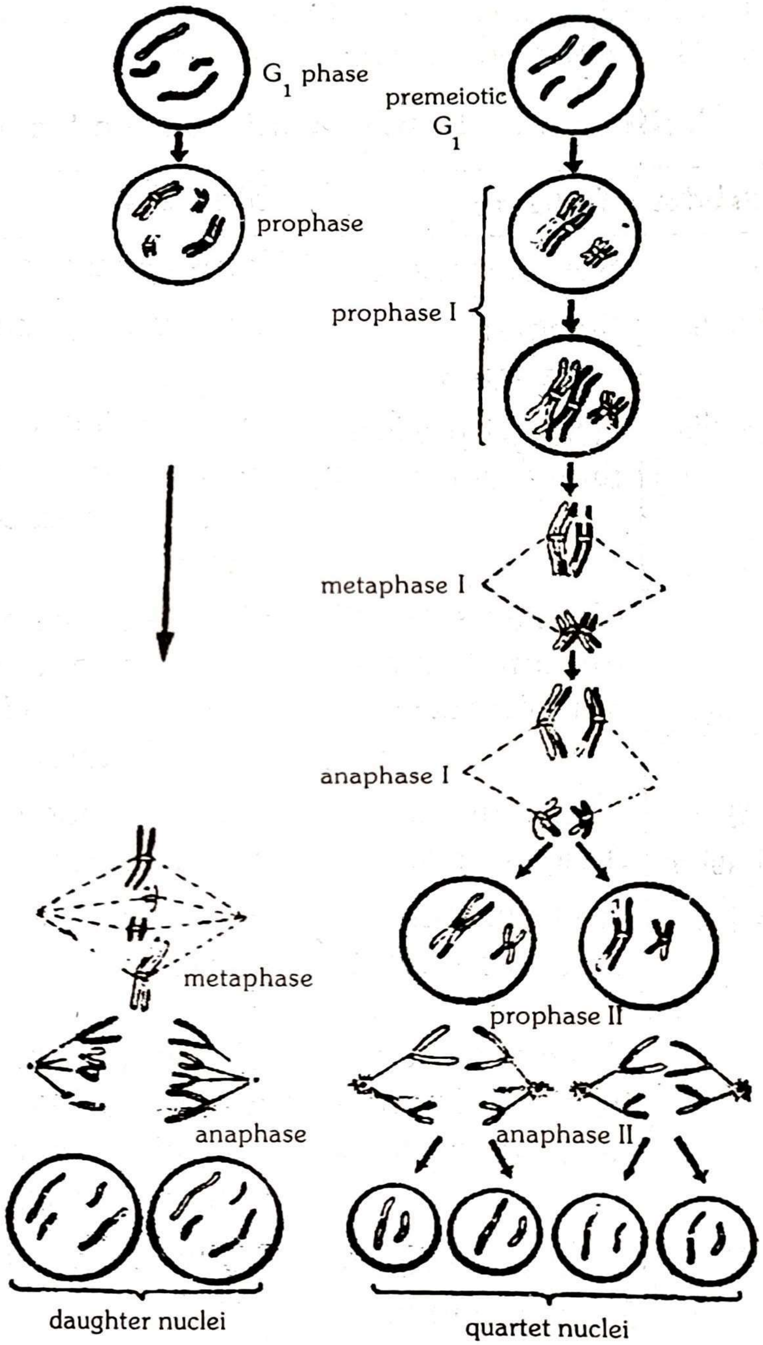


Fig. Diagrammatic representation of comparison between mitosis and meiosis.

1 **Metaphase II :** Centromere are exactly on the equatorial plane. Centromere are connected by spindle fibres on both sides. Nuclear membrane and nucleolus absent.

2 **Anaphase II :** Longitudinal splitting of centromere.

3 **Telophase II :** Nuclear membrane & nucleolus reappear.

Cytokinesis separates each nucleus from the others and thus the process of meiotic nuclear division completes.

Table : Differences between mitosis and meiosis

Characteristic	Mitosis	Meiosis
Location	Somatic tissues	Reproductive cells only
Shape of cells	Generally rectangular	Generally spherical
Daughter cells	One cell produces two daughter cells	On completion of meiosis, four daughter cells are produced from one cell.
Genetic variation	Maintains genetic uniformity among daughter cells	Generates genetic variability due to segregation and recombination.
Number of nuclear division	Each nucleus divides once	Nucleus undergoes divisions twice.
Prophase I	Homologous chromosomes do not pair. Chiasama cannot be seen. There is no DNA synthesis	Homologous chromosomes pairs. Chiasma is observable About 0.3% of the DNA is synthesized during zygotene and pachytene
Prophase II	Chromosomes are 2n in number. Sister chromatides show relational coiling.	Chromosomes number is only n. Relational coiling between sister chromatides is absent.

	Chromosomes are very long. It is quite long in duration.	Chromosomes are small. It is of relatively short duration.
Metaphase I	2n chromosomes are clearly seen. Centromeres of all the chromosomes lie on the equatorial plane.	The number of bivalents is n. Chromosomes lie on the either side of equatorial plane.
	Each chromosome has two chromatides	Each bivalent chromosome has four chromatides.
Metaphase II	Chromosomes are relatively longer.	Chromosomes are much smaller.
Anaphase I	Two sister chromatides move to the opposite poles.	Homologous chromosome from each bivalent moves to the opposite poles.
	Centromere divides longitudinally of each chromosome.	Centromere do not divide.
Anaphase II	Generally, a single nucleus divides in a cell.	In all the stages of second Meiotic division, two nuclei diploid in one parent cell.
Telophase	Chromosome completely uncoil.	Chromosomes do not uncoil completely.
Cytokinesis	In all the species, cytokinesis takes place.	In some species, cytokinesis does not take place.
	Each cells produces two daughter cells	Each cell gives rise to four haploid cell, the resulting structure is called tetrad.
	Daughter cells generally differentiate as body cells.	Daughter cells generally differentiate into spores, gametes.

* Number of meiosis in pollen mother cell (PMC)

$= \frac{n}{4}$ Where n = no. of pollens

$$\underset{\text{PMC}}{(2n)} \xrightarrow{\text{meiosis}} \underset{\text{Pollen tetrad}}{\begin{array}{|c|c|} n & n \\ \hline n & n \end{array}} \longrightarrow \underset{\text{4 pollens}}{(n)\ (n)\ (n)\ (n)}$$

* No. of meiosis in seed : $n + \frac{n}{4}$ where n = no. of seeds

(a) For 100 ovules $\Rightarrow$ 100 meiosis

(b) For 100 pollens $\Rightarrow$ 25 meiosis

100 seeds $\Rightarrow$ 125 meiosis

* No. of mitosis = n – 1 where n = no. of cells.
* Endosperm of angiosperm = 3n (n = no. of chromosomes)

Endosperm of Gymnosperm = n

Endosperm of angiosperm (3n)

♀ (2n) x ♂ (2n) plant

↓ gametogenesis (microsporogenesis)

Secondary nucleus (2n) ♂ gamete (n)

Endosperm (3n)

Prokaryotes and Eukaryotes

On the basis of well defined nucleus, living Organisms are grouped into :-

(1)Prokaryotes : Lack of well defined nucleus, where it is called nucleoid or prokaryon. eg. virus, bacteria and Blue green algae (BGA). Nucleoid does not have a true chromosome.

(2) Eukaryotes : Well defined nucleus present but nucleus may also be absent in some specialised cells of eukaryotes e.g.

matured RBC of mammals are without any nuclei, that is why its name is corpuscles, instead of cells.

Table : Differences between eukaryotic and prokaryotic cells

Eukaryotic cells	Prokaryotic cells
i. Nucleolus is present in the nucleus	i. Nucleous is absent.
ii. Chromosome ends are attached to the nuclear membrane.	ii. Chromosome are attached to plasma lemma.
iii. During cell division, spindle apparatus is organized.	iii. Spindle 'fibres are absent
iv. Most of the ribosomes are attached to endoplasmic reticulum. Some ribosomes are free in the cytoplasm.	iv. All ribosomes are free in cytoplasm.
v. Cytoplasm contains several membranous structures.	v. Cytoplasm does not have membranous structures.
vi. Cells contain mitochondria.	vi. Mitochondria absent.
vii. All green plant have typical chloroplasts which have typical grana.	vii. Chloroplast is absent
viii. Cytoplasm has a system of microtubules which may provide stability to the cytoplasmic structures.	viii. Cystoplasm does not have any microtubules
ix. DNA complexed with histone and non-histone proteins to form chromatin fibres.	ix. Generally, DNA is naked and not complexed with histones.
x. The amount of DNA per cell is many fold greater than that in prokaryotes.	x. The amount of DNA/cell is a small fraction of that found in eukaryotic cells.
xi. The nucleus is enclosed by two concentric unit membrane	xi. The region containing chromosome is not surrounded by a membrane.

24 Mendel's Laws

Mendel's life : Gregor Johann Mendel was born on 22 July, 1822 in a farmer's family in the village Moravia near Brunn in Austria, now part of Czechoslovakia. His brief history is as follows :

A brief chronology of mendel's scientific and literary works

July 22, 1822	Born in Heinzendorf, Moravia (Brunn) Austria.
1840	Graduated from Gymnosium in Troppau.
1847	Ordained as a priest.
1849	Appointed as substitute science teacher in Znaim high school.
1851-53	He was sent by the monastery authorities to the university of Vienna for higher studies in science.
1854	He joined the Brunn modern school as a teacher of physics and natural history.
1857	He began to collect pea seeds for his experiment from all over Europe.
1862	Become one of the founder member of Natural History Science Society, Brunn.
1865	Gave first two lectures (on 8th February and 8th March) on his pea experiment in Brunn Natural Science Society.
1866	Published research paper entitled "Experiments on Plant Hybridization" in Volume 4 of the "Proceedings of the Natural History Science Society, Brunn.
1868	Elected abbot of Monastery of St. Thomas.

1869	Gave lecture on *Hieracium* experiments at Natural History Science Society.
1870	Papers related *Hieracium* and *Brunn tornado* published in the proceedings of the society.
1873	Wrote last letter to Professor Nageli.
1884	January 6, died because of bright's disease.
1900	Rediscovery of the mendel's work by **Hugo de Vries in Holland** (Netherland Dutch), Carl **Correns in Germany** and **Erich von Tschermak in Austria.**

Mendel's Work :

Mendel selected the garden pea ***(Pisum sativum L)*** for his experiment. He found the garden pea plant as the most suitable material because of

1) The garden pea was **easy to culture** either in field or in pot.
2) It had **Shorter life cycle** or was of short duration.
3) It had highly **self pollinated** flowers.
4) Well defined constrasting heritable characters.
5) Easy emasculation & hybridization.

Mendel selected seven pairs of constrasting characters for his study.

Table : Seven pairs of contrasting characters studied by Mendel.

Plant Parts		Characters	Dominant	Recessive
Seed	i	Shape	Round	Wrinkled
	ii	Cotyledon colour	Yellow	Green
	iii	Seed coat colour	Grey	White
Pod	i	Pod shape	Inflated	Constricted
	ii	Pod colour	Green	Yellow
	iii	Position of pod	Axial	Terminal
Stem	i	Plant height	Tall	Dwarf

Before mendel's work, several workers conducted the heredity experiment i.e hybridization work, but they were failed. Those workers considered the individuals as a whole complex of characters.

Whereas Mendel's success was mainly based on the fact that he selected a single character at one time.

Reason for Mendel's success :

1) Considered one trait (character) at one time.
2) Selected contrasting (opposite) pairs of characters i.e. 7.
3) All the characters were independent of each other.
4) Characters were present on different chromosome i.e. there were no linkages.
5) Accurate account of experiment.
6) Used appropriate symbol, sign & terminology.

Mendel's observations :

Mendel crossed the tall plants with dwarf plants. [All the plants of F_1 generations were tall. The initial cross between two varieties is called the parental or P_1 generation and their offsprings whether in seed form or as plants are called the F_1 (Filial) generation. The succeeding generations produced from the crossing of F_1 are called F_2 generation and so on.]

When Mendel self-fertilized the F_1 plants, the offsprings were both tall and dwarf plants in the ratio of 3:1. He found that the similar patterns were also observed in other six contrasting traits. He also found that the reciprocal crosses gave the same results i.e. pollen or egg of the parent variety did not matter.

Table : Results of Mendel's original crosses for seven pairs of characters

S.No.	Structure	Character	Dominant	Recessive	F_2 Ratio
1.	Seed	Shape	5475 Round	1850 Wrinkled	2.96:1
2.	Cotyledon	Colour	6022 Yellow	2001 Green	3.01:1
3.	Seed coat	Colour	705 Grey	224 White	3.15:1
4.	Pod	Shape	882 Inflated	299 Constricted	2.95:1
5.	Unripe Pods	Colour	428 Green	152 Yellow	2.82:1
6.	Flower	Position	651 Axial	207 Terminal	3.14:1
7.	Plant	Length	787 Tall	277 Dwarf	2.84:1
	Total		14,949	5010	2.98:1 or 3:1

Although Mendel did the brilliant work but due to the following reasons, his work was not recognised till 1900.A.D. :-

1) Due to predominance and wider acceptability of the Darwin's theory of continuous variations, the workers of that time were unable to understand the principle of heredity.
2) Due to the use of mathematical calculations and probability law, his works were not accepted by the biologists.
3) The biologists did not know the chromosomal behaviour and the phenomenon of fertilization.
4) He did not publish his works in the leading journals.
5) He failed to proof his experiment on *Hieraceum* as suggested by Prof. Nageli.

Mendel's Laws :

Mendel's works were confirmed & rediscoverd in 1900 individually by Hugo de Vries (Dutch), Carl Correns (German) & Erich Von Tschermark (Austrian). Then three fundamental principles of genetics were universally accepted.

1) Law of segregation or purity of gametes.
2) Law of Dominance or Law of uniformity of first filial generation.
3) Law of Independent assortment.

1 Law of Segregation or Purity of gametes :

In heterozygous state, the dominant and the recessive alleles remain together throughout the life without contaminating or mixing with each other. During gametes formation these alleles separate or segregate from each other so that each gamete gets only dominant or recessive allele. For understanding the law of segregation, here are four principles:

a) Hereditory character is determined by a particular factor (now called gene)
b) These factors occur in pair i.e. each gene has two or more alternative forms, known as alleles.
c) In the formation of gametes, these factors are separated in such a manner that only one of the pair is transmitted to a particular gamete.
d) When male & female gametes unite to form a zygote, the double of the chromosome number is returned.

Homozygous and Heterozygous : The individual being identical alleles at both gene loci for a particular phenotypic character is called homozygous individual. The individual or genotype having different allele for a particular trait is called heterozygous individual or genotype.

Hemizygous : An individual having only one allele of a gene in place of normal two allele is called hemizygous individual.

After selfing of pea plant for several generations, Mendel observed that only tall progenies from the tall plant and only dwarf progenies from the dwarf plant were obtained. It means the parent plants were in homozygous state i.e. the alleles of tall plants would be TT and of dwarf plants would be tt. During the gametogenesis homozygous tall plants (TT) would produced only (T) type of gametes and homozygous dwarf plants (tt) would produced only (t) type of gametes. But heterozygous plants (Tt) would produced both types of gametes i.e (T) type and (t) type but in pure form.

Homozygous parents

Tall plant (TT) $\xrightarrow{\text{gametogenesis}}$ T gamete, T gamete

Dwarf Plant (tt) $\xrightarrow{\text{gamete formation}}$ (t) gamete, (t) gamete

Heterozygous parents

Tall plant (Tt) $\xrightarrow{\text{gametogenesis}}$ T gamete, (t) gamete

In heterozygous tall plant (Tt) the tall (T) allele is dominnt over the dwarf (t) allele, therefore the plant will be tall but during gamete formation both the alleles (T) and (t) separate from each other and form the pure gametes.

2 Law of Dominance :

Mendel observed that the F_1 individuals derived from the crosses between two different varieties having different characters, showed only one of traits & never the other. Such trait in F_1 generation was called dominant and the other which

did not appear in the F_1 generation but reappeared in F_2 generation was called recessive. Mendel was fortunate to select seven pair of contrasting characters which exhibited dominance. Now it is clear that the the hybrid of F_1 generation always be uniform, therefore the law of dominance can be renamed as **law of uniformity of first filial generation.**

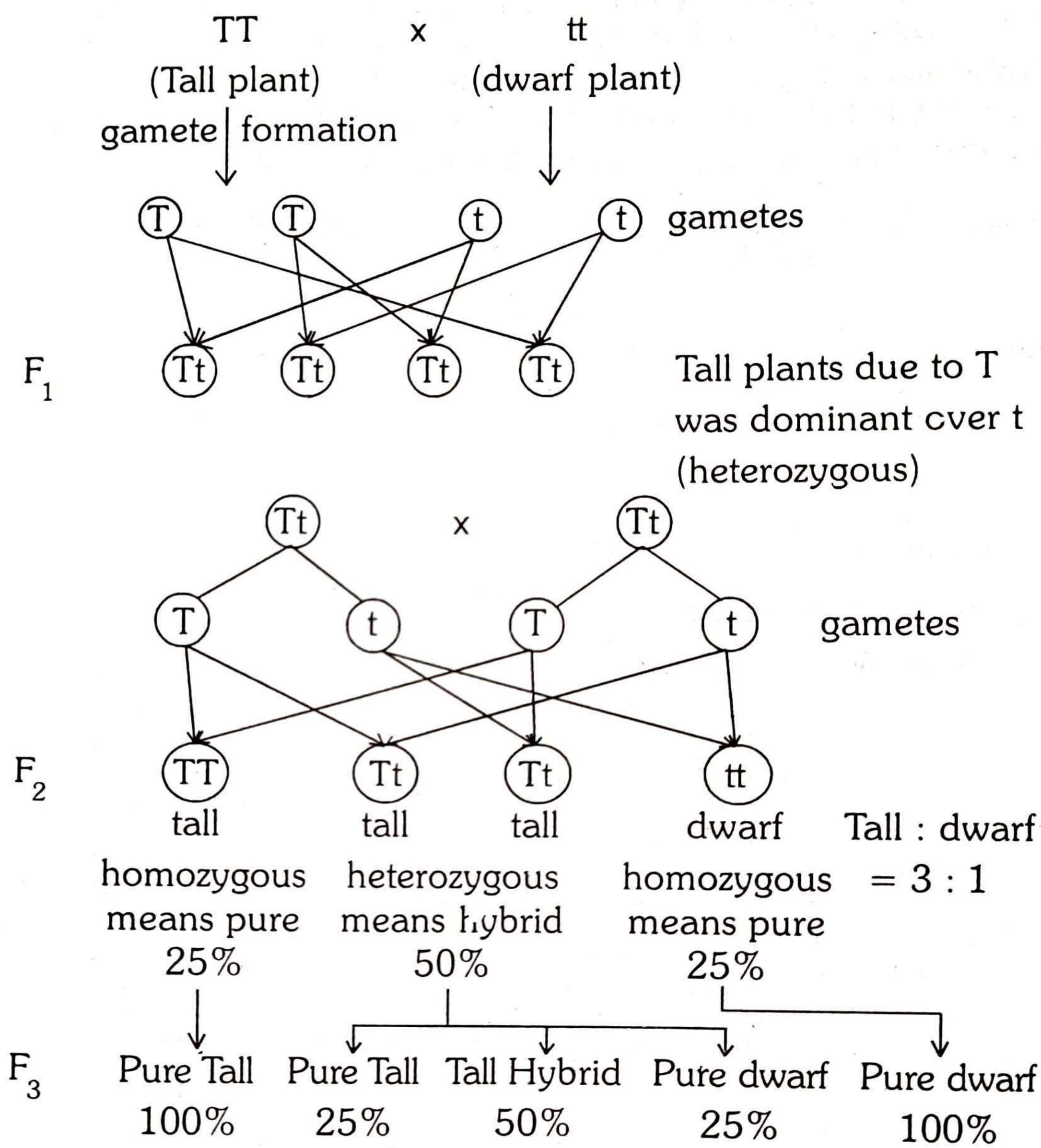


Fig : Inheritance of plant height

3 Law of Independent Assortment :

According to this law, segregation and assortment of alleles for different characters are independent to each other and follows the multiplication of law of probability. But this principle is

applicable only on the alleles of genes located on the different chromosomes and not to the linked genes.

Mendel crossed two varieties of pea i.e yellow coloured round seeded plant with green coloured wrinkled seed plant. The F_1 seeds obtained were yellow coloured & round seed because yellow is dominant over green and round is dominant over wrinkle. In F_2 generation. Four types of seeds were obtained in the ratio of 9:3:3:1. This ratio was also expected from independent segregation of seed shape and cotyledon colour. From the Mendel's observation it is concluded that seed shape and cotyledon colour segregate independently of each other.

Parent: Yellow round seed YYRR x Green wrinkled seed yyrr

Gamete: YR x yr

F_1 generation: yellow round seed Yy Rr

Gametes: YR, Yr, yR, yr

♂ male gamete
♀ female gamete

F_2 generation

♀ \ ♂	YR ♂	Yr ♂	yR ♂	yr ♂
YR	YYRR Yellow Round	YYRr Yellow Round	YyRR Yellow Round	YyRr Yellow Round
Yr	YYRr Yellow Round	YYrr Yellow Wrinkled	YyRr Yellow Round	Yyrr Yellow Wrinkled
yR	YyRR Yellow Round	YyRr Yellow Round	yyRR Green Round	yyRr Green Round
yr	YyRr Yellow Round	Yyrr Yellow Wrinkled	yyRr Green Round	yyrr Green Wrinkled

Phenotypic ratio: 9 Round Yellow : 3 Round Green : 3 Wrinkled Yellow : 1 Wrinkled Green

Fig. : A checkerboard showing 16 combinations obtained in a dihybrid cross involving characters for seed shape and seed colours.

The method of working out F_2 progeny using different kinds of male & female gametes is known as checkerboard.

Table : Summary of the genotypes and phenotypes obtained in F_2 of the cross shows in the Fig.

Genotype	Genotypic ratio	Phenotype	Phenotypic ratio
YYRR YYRr YyRR YyRr	1 2 2 4	Yellow and round	9
YYrr Yyrr	1 2	Yellow and Wrinkled	3
yyRR yyRr	1 2	green and round	3
yyrr	1	green and wrinkled	1

Deviations from Mendel's law :

1) Mendel found that each of 7 characters considered was controlled by a single gene but there may be more than or equal to (⩾) 2 genes responsible for a particular character.
2) According to Mendel, one allele dominates over the other and the phenotypic ratio in F_2 is 3:1 but in *Mirabilis jalapa* is 1 (red) : 2 (pink) : 1 (white) when red flower plant is crossed with white flower plant.
3) According to Mendel, there were only two alternative forms for each character means only two alleles were present for each character but there may be several phenotypes for a character. Therefore, concept of alternative allelomorphs has been modified by the concept of multiple allelism. Existence of more than two alleles at a locus is called multiple allele e.g. several alleles exhibit red eye colour (W^{+s}, W^{+c}, W^{+g}) in *Drosophila*.

Monogenic/Monohybrid cross : Here only one pair of contrasting character was taken.

The ratio in F_2 generation were

Genotypic ratio : 1 : 2 : 1

Phenotypic ratio : 3 : 1

Dihybrid cross : Here 2 pairs of contrasting characters were taken. The ratio in F_2 generation

Phenotypic ratio : 9 : 3 : 3 : 1 (Four types)

Genotypic ratio : 1 : 2 : 2 : 4 : 1 : 2 : 1 : 2 : 1 (9 types)

Trihybrid cross : 3 pairs of contrasting characters will show

Phenotypic ratio : 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1

F_1 will produce 8 kinds of gametes & 64 combinations in F_2

Back cross & Test Cross :

Usually F_1 individuals obtained from the cross between the parents are selfed to get F_2 progeny. But when the F_1 individual is crossed with either of the two parents, such cross is known as back cross.

And when the F_1 individual is crossed with recessive parent only, is called test cross. The test cross is used to determine the genotype of the parent whether an individual is homozygous (means pure) or heterozygous (hybrid).

Example :

(x) plant x dwarf plant (recessive)
(tt)

F_1

If all F_1 is tall, then (x) means TT.
If 50% of F_1 is tall then (x) means Tt.

TT x tt
Tall dwarf

gametes: T T gametes: t t

♀ \ ♂	t	t
T	Tt tall	Tt tall
T	Tt tall	Tt tall

All tall (hybrid)

Tt × tt

hybrid tall dwarf

T t t t gametes

♀ \ ♂	t	t
T	Tt tall	Tt tall
t	tt dwarf	tt dwarf

50% hybrid tall
50% pure dwarf

If F_1 individual is crossed with the dominant parent, such cross is called back cross and the result is :

TT × Tt

tall parent F_1 individual (tall)

T T T t

♀ \ ♂	T	t
T	TT Pure Tall	Tt hybrid Tall
T	TT Pure Tall	Tt hybrid Tall

50% Pure tall
50% hybrid tall
but 100% tall plant.

This is the result of backcross one i.e. BC_1.

❋

25 Dominance & Gene Interaction

Dominance

Dominance is the phenomenon of expression of only one character or allele in heterozygous state. It is of four types :-

a) Co-dominance or No-dominance
b) Incomplete or Partial dominance
c) Complete dominance
d) Over dominance

a) Co-dominance/No-dominance : In such condition both alleles of a gene express themselves in heterozygous condition e.g. human blood group (ABO). AB blood group possess both the antigens A & B. The genotypic ratio in F_2 is 1:2:1.

b) Partial/Incomplete dominance : In such condition a dominant allele does not suppress completely the phenotypic expression of recessive allele. e.g. the cross between red flower variety of Snapdragon (*Antirrhinum mazus*) with its white flower variety produces pink flower in all the plants in F_1 generation and in F_2 three types red, pink and white are obtained in the ratio of 1:2:1.

c) Complete dominance : In this condition one allele completely suppresses the expression of other. e.g round seed shape in pea is completely dominant over wrinkled seed shape and the ratio of monohybrid in F_2 is 3:1.

d) Over dominance : Here the intensity of character is greater in heterozygotes than in the concerned homozygotes e.g in maize, the heterozygote is more pigmented than either homozygote in presence of certain R alleles.

Penetrance :

It refers to the statistical regularity with which a gene

produces its effect when present in the requisite homozygous or heterozygous state. It means penetrance is the ability of a gene or a combination of genes to be expressed phenotypically to any degree. It may be either complete or incomplete.

In complete penetrance genes always produce the expected phenotype whereas in incomplete penetrance the genes fail to produce complete phenotypic expression e.g. In man the tendency to develop diabetes mellitus (excess sugar in blood) is controlled by certain genes. However not every one carrying the genes for diabetes actually develop the condition. It means genes have incomplete penetrance.

Expressivity : Is the degree of effect produced by a penetrant gene. e.g. in man polydactyly (more than five fingers) may be penetrant in the left hand (6 fingers) and not in the right hand (five fingers).

The penetrance of a gene and expressivity are influenced by environmental factors.

Pleiotropism : A single gene (allele) often influences more than one phenotypic trait; such multiple effect of a single gene is known as pleiotropism. e.g. the gene for a disease phenylketonuria in man has pleiotropic effect. It produces various abnormal phenotypic traits collectively called syndrome.

Lethality : Lethality is such condition where death of a certain genotype occurs prematurely. e.g. In mice a dominant allele Y for yellow coat is lethal in homozygous state.

F_1	(Yy)	x		(Yy)	
	Yellow	↓		Yellow	
F_2	1 (YY) :	2(Yy)	:	(yy)	
	Dies	yellow		black	

Phenotypic ratio : 2 : 1 or 0 : 2 : 1

Genotypic ratio : 2 : 1

Gene interaction : Such phenomenon of two or more genes which affects the expression of each other in various ways in the development of a single character of an organism is called gene interaction.

(1) Complementary genes : Bateson & Punnet found flower coloured of sweet pea *(Lathyrus odoratus)* in the ratio of 9:7 (9 coloured & 7 white) instead of 9:3:3:1 in F_2.

(2) Epistasis : Here one gene masks the effect of other. The dominance works at interallelic and intragenic level while epistasis works at intergenic level.

a) Recessive epistasis : 9 : 3 : 4 (in F_2)

e.g. cross between coloured mice & albino mice.

Product will be Agouti : Coloured : Albino

9 3 4

b) Dominant epistasis : 12 : 3 : 1 (F_2)

e.g cross between two heterozygous white coated dogs.

Product will be White : Black : Brown

12 : 3 : 1

(3) Inhibitory gene action : 13 : 3

Here one dominant inhibitory gene prevents the expression of another dominant gene and thus 9 : 3 : 3 : 1 F_2 ratio is modified in 13 : 3. e.g. seed colour in maize 13 white : 3 red.

(4) Duplicate genes/Duplicate Epistasis : 15 : 1

A modified 15:1 ratio was observed by G.H. Shull when he studied shephered's purse (capsella). Phenotypic ratio 15 : 1 in F_2 (15 triangular shaped capsule and 1 top shaped capsule).

(5) Polymeric/Additive gene action : 9 : 6 : 1

In the coat colour of Duroc-Jersey pigs, the F_2 phenotypic ratio : 9 red : 6 sandy : 1 white.

*

26 Linkage & Crossing Over

After the detailed study of meiosis we came to the conclusion that independent assortment of characters is based on independent assortment of non-homologous chromosomes. It means if two characters have to assort independently these should be located on separate non-homologous chromosomes. The appearance of new traits and combination of traits is the resultant of the law of segregation and independent assortment.

But Bateson & Punnet (1906) found in Garden Pea that two pairs of alleles did not assort independently and the similar case was found in Drosophila by T.H. Morgan (1910). Here both the genes were located on the same chromosome, therefore they inherited together. Such genes are called linked genes and the group of such genes are known as linkage group. Such genes have tendency to remain together during the process of inheritance.

The strength of linkage depends upon the distance between the linked genes. Such linked genes can be separated by the process of crossing over or recombination. The linked genes of relatively close loci transmit together from generation to generation but of relatively distant loci are frequently separated by crossing over. The crossing over varies from 0-50% and will never cross 50% and the non-crossover varies from 50-100%.

Bateson & Punnet formulated the hypothesis 'Coupling and repulsion hypothesis' to explain the lack of independent assortment in the result obtained from the dihybrid cross between homozygous sweet pea (*Lathyrus odoratus*) having a dominant allele for blue or purple flowers and long pollen with another homozygous double recessive plant with red flowers & round pollens. But they could not explain the exact reasons.

T.H. Morgan explained that in coupling phase the two genes are located on the same chromosome but in repulsion these genes are present on two different homologous chromosomes Morgan named the phenomenon of inheritance of linked genes as linkage. Morgan's concept developed the theory of linear arrangement of genes in the chromosome which helped in the construction of genetic or linkage maps of chromosomes.

A line on which the genes are represented by points separated by distances proportional to the amount of crossing over is called **linkage map** or **chromosome map** or **genetic map.** The genetic map displays the exact location, arrangement and combination of genes in a linkage group or chromosomes; which is useful in predicting the results of dihybrid & trihybrid crosses. The genetic map helps in the transfer of genes from the donor varieties to the recipient varieties.

*

27 Sex linked, Sex influenced & Sex limited traits

In monoecious/hermaphrodite/bisexual (male & female on the same individual) individuals, the character or trait of the F_1 generation is always irrespective of their gender. But in dioecious (male & female on the other individual) individuals there may be two types of traits :

i) Some traits do not show any differences in the reciprocal crosses i.e

$$A♀ \times B♂\ ,\ B♀ \times A♂$$

ii) Some traits show the differences in reciprocal crosses.

Such traits which do not show any differences in the reciprocal crosses; are located on the autosomes and the traits which show the differences are either located on sex chromosomes or if located on the autosomes, are influenced by or depend on the sex of the individual which carries it.

The traits which are located on sex chromosomes are called sex linked traits. The traits whose expression is governed or influenced by the sex (maleness or femaleness) of the individual are called sex influenced traits.

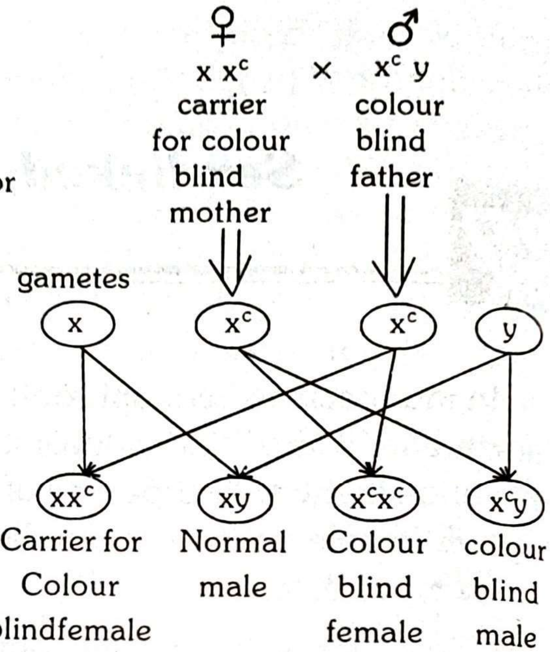
The traits whose expression is dependent on the sex (♀ or ♂) of the individual who carries it, are called sex limited traits. Such trait is expressed in one sex only and not in the other.

Sex linked traits :

Example : Colour blindness and haemophilia in human beings. Colour blind man is unable to differentiate between red colour and green colour. The gene for red-green colour blindness is located on x-chromosome.

♀ \ ♂	x^c	y
x	x x^c carrier for colour blindness ♀	xy normal ♂
x^c	x^c x^c colour blind ♀	x^cy colour blind ♂

or



In haemophilia, the man lacks the factor responsible for blood clotting. Therefore even a minor cut may cause prolonged bleeding leading to death.

♀ x x^h carrier mother × ♂ x y normal father

gametes

♀ \ ♂	x	y
x	x x normal ♀	xy normal ♂
x^h	x x^h carrier female	x^hy haemophilic male

Such traits are transferred from mother to the son and never from the father to the son because they are X-linked and recessive in character. A carrier woman transmits these diseases to the 50% of her sons, even if the father is normal.

Non-disjunction of sex chromosomes

Nondisjunction means the absence of separation of two homologous X-chromosomes (in Drosophila) during anaphase I of meiosis. In such case, both x-chromosomes go together to the

same pole and other pole will get no x-chromosome. In 1916, C.B. Bridges reported it in Drosophila. However it happened rarely.

♀		♂
$x^w x^w$	×	x^+y
White eyed		red eyed

	gametes ♀	♂ x^+	y
normal disjunction	x^w	x^wx^+ red eyed ♀	x^wy white eyed male
nondisjunction (Primary)	x^wx^w	$x^wx^wx^+$ Super female (dies)	x^wx^wy white eyed female
	-	x^+ red eyed male	y Super male (dies)

Such a nondisjunction with normal female parent is called primary nondisjunction.

♀		♂
$x^w x^w y$	×	$x^+ y$
White eyed (result of primary non-disjunction)		red eyed

	gametes ♀	♂ x^+	y
normal disjunction	x^w	x^wx^+ red eyed ♀	x^wy white eyed ♂
	x^wy	x^wx^+y red eyed ♀	x^wyy white eyed ♂
secondary nondisjunction	x^wx^w	$x^wx^wx^+$ super female (dies)	x^wx^wy white eyed ♀
	y	x^+y red eyed ♂	yy dies

Such a nondisjunction with white eyed ($x^wx^w y$) female (result of primary nondisjunction) parent is called secondary nondisjunction.

The cytological study of the exceptional white eyed females ($x^w x^w y$) definitely suggested Mendelian factors or genes were carried on chromosomes. Therefore, nondisjunction of sex chromosomes is the strong evidence for 'chromosomal theory of inheritance'

Sex-influenced traits : In some organisms, some characters are influenced by the sex of the organism. For example : horns in sheep. Horned character is dominant in male but recessive in female. This influence is believed to be mainly due to male & female hormones.

Genotype	Male	Female
h^+h^+	horned	horned
h^+h	horned	hornless
hh	hornless	hornless

Sex limited traits : e.g. premature baldness is expressed only in the presence of a certain level of male hormone (androgenic). Milk production is also sex limited trait. In such cases genes for the particular traits are carried by both male & female.

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28 Cytoplasmic or Extranuclear Inheritance

The inheritance of almost all traits or characters from generation to generation is governed by the genes of nuclear chromosomes. But the inheritance of some traits is also governed by the cytoplasm. Since major part of the cytoplasm of the zygote is derived from the female gamete and male gametes carry little or no cytoplasm means this inheritance is governed by female parent.

The inheritance of the traits governed by the cytoplasm or female parent or extranuclear chromosomes is called Cytoplasmic/maternal/extranuclear inheritance .

Genes/DNA/Chromosomes are also present in the Cytoplasmic organelles, like chloroplasts & mitochondria are solely responsible for the cytoplasmic inheritance.

Genes present in the cytoplasm are called plasmogenes or plasmones.

Features of Cytoplasmic Inheritance :

1) In the inheritance of the nuclear genes, male & female parent contribute equally to the progeny and its reciprocal crosses between the parents yield progenies of the identical phenotype except for sex-linked genes. But in the cytoplasmic inheritance only maternal effect appear in the progeny because eggs or ova (female gametes) contribute large amount of ooplasm and many extra nuclear genes in the form of inactive mRNA, rRNA & tRNA and also in the form of DNA of mitochondria, chloroplasts & endosymbionts.Therefore reciprocal crosses yield different results (non mendelian).

2) Certains traits of F_1, F_2 or F_3 progeny are not the expression of their own genes, but rather those of the maternal parents. The substance is which produce the maternal effects are transcriptional products i.e mRNA, r RNA, tRNA.

3) Inheritance of some characters like male sterility in maize is governed by mitochondrial DNA. This maternal inheritance of male sterility was discovered by Rhoades (1933) in Maize.

   Plastid inheritance in four O'clock plant, *Mirabilis jalapa* was discovered by C. Correns (1908). He found the colour of leaf was totally governed by the colour of the female parent.

   Jenkens (1924) discovered iojap colour (not full developed colour) in leaves of Maize (corn).

   Inheritance of kappa particles in Paramecium was discovered by Soneberg (1943). Ruthsanger (1960) discovered the uniparental (♀ parent) inheritance of streptomycin resistance in chlamydomonas (unicellular green algae).

4) Ethydium bromide has a capacity to mutate only cytoplasmic genes. Mutation caused by such chemical is heritable which showed the evidence for cytoplasmic inheritance.

Practical application of cytoplasmic inheritance :

1) It plays an important role in the biology of several organism.
2) Cytoplasmic male sterility (CMS) lines have been developed in several crops viz. maize, pearl millet, sorghum, cotton etc. Hybrid maize seed may be produced without detasselling (removal of tassel) by utilizing cytoplasmic/cytoplasmic genetic male sterility.
3) It plays key role in mapping of chloroplast and mitochondrial genome in several species viz. yeasts, chlamydomonas, maize etc.
4) Role of mitochondria in the manifestation of heterosis is gaining importance.
5) Mutation of chloroplast DNA & mitochondrial DNA leads to generation of new variants.

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29 Modes of Reproduction & Pollination Control

Genetic constitution (i.e homozygous or heterozygous) of the crops is determined by the mode of reproduction. The knowledge of the mode of reproduction is important for hybrid production.

Apomixis : In apomixis, sexual reproduction is either suppressed or absent. When sexual reproduction is suppressed (i.e. present), apomixis is called facultative and when absent, apomixis is called obligate apomixis.

Facultative apomixis is more common. When embryo arises from haploid cells, apomixis is **nonrecurrent** because its progeny can't be maintained further and when embryo arises from diploid cells, apomixis is called **recurrent.**

Apomixis is synonym of agamospermy.

Apomixis is of two types :-

A) **Adventitious embryony :** Embryo is developed directly from vegetative cells of ovule such as nucellus, integument & chalaza. No production of embryo sac. e.g. **Nucellar seedlings** in **mango, citrus,** orchids etc.

B) **Gametophytic apomixis :** Embryo is developed from egg cells or other cells of embryo sacs but without fertilization. In recurrent apomixis, unreduced embryo sacs are developed by a process of **apomeiosis.** Apomeiosis is of two types :

1) **Apospory :** Unreduced embryo sacs are developed from some vegetative cells of ovule through a series of mitotic divisions and without meiosis. e.g. some species of Hieraceum, Malus, Crepis, Ranuculus, Orchids etc.

Modes of reproduction

- Asexual reproduction (No involvement of Fusion of ♂ & ♀ gametes)
  - Vegetative (development of new plants from vegetative parts of Plant
    - Underground (modified) stems; e.g. Tuber-Potato; Bulb-onion. garlic; Rhizome-zinger, turmeric; Corm-Bunda, arwi (colocasia sp.)
    - Sub-aerial (modified) stems : e.g. runner, sucker, stolon
    - Bulbil (modified flowers which develop into plants directly without formation of seeds) eg. garlic, cardamom
    - Artificiel vegetative reproduction: e.g. stem cuttings, layering, budding, grafting, gootee.
  - Apomixis (Seeds are formed but embryos are developed without fertilization)
    - Adventitious embryony
    - Gametophytic apomixis
      - Apomeiosis
        - Apospory
        - Diplospory
          - Parthenogenesis
            - Gonial
            - Somatic
          - Pseudogamy
            - Gonial
            - Somatic
- Sexual reproduction (involvement of fusion of ♂ & ♀ gametes and its fusion develops into an embryo. After pollination, the pollen tube finally enters the ovule through a small pore called micropyle and discharges two sperms into embryo sac. One sperm fuses with the egg cell producing a diploid zygote. This is called fertilization. Other sperm fuses with secondary nucleus leading to formation of triploid primary **endosperm** nucleus (called triple fusion) which produces endosperm. During seed development endosperm provides nutrition to the developing embryo.

2) **Diplospory** : Embryo sac is produced from the mega spore which may be haploid or more generally, diploid. In apomictic species, diploid megaspores are produced by modified meiosis.

The embryos in such embryo sacs may be arised by either parthenogenesis or pseudogamy.

i) **Parthenogenesis :** Embryo is developed from the embryo sac without **pollination**. Pollination is the landing of pollen onto the stigma of a flower. Parthenogenesis is of two types :-

a) Gonial parthenogenesis : embryo is developed from egg cell.

b) Somatic parthenogenesis : Embryo is developed from some cells of the embryo sac other than the egg cell.

Generally 'Parthenogenesis' is used as a synonym of somatic parthenogenesis.

ii) **Pseudogamy** : Pseudo means false & gamous means marriage. Pollination occurs but fertlization of egg cell does not take place however fertilization of secondary nucleus occurs. Pseudogamy is of two types.

a) gonal pseudogamy : Embryo is developed from egg cell.

b) somatic pseudogamy : Embryo is developed from some other cells of embryo sac.

Vybrid : is a progeny obtained from a cross between two facultative apomicts. The vybrid itself reproduces through facultative apomixis and is maintained by harvesting the seeds of only F_1-like apomictic plants in every generation.

Flower :

Hermaphrodite/Perfect flower : Such flower contains both stamens (♂) and Pistil (♀).

Staminate Flower : Such flower contains only stamens not pistil.

Pistillate Flower : Such flower contains only pistil & not stamen.

Monoecious plant : Here staminate & Pistillate flowers occur on the same plant. e.g. maize, colocasia, castor, coconut etc.

Dioecious Plant : Here staminate & pistillate flowers occur on different plants e.g. Papaya, date palm, Pistachio etc.

Anthesis : In the process of Flowering, the first opening of a flower is called anthesis. It fascilitates the pollination by opening of flower.

Self pollination/autogamy : In Such pollination, pollen from an anther falls on the stigma of the same flower.

Cross-Pollination/allogamy : Here pollens from flowers of the one plant are transmitted to the stigma of flowers of the another plant by wind (anaemophily), water (hydrophily) or insects (entomophily).

Geitonogamy : When pollens from a flower of one plant fall on the stigmas of other flowers of the same plant, this situation is called geitonogamy. The genetic consequence of geitonogamy is the same as those of autogamy.

Mechanisms promoting self-pollination :

1) **Cleistogamy** : Here Flowers do not open at all i.e complete closed flowers. e.g. some varieties of wheat, oat, barley and in some grasses.
2) **Chasmogamy** : Here Flowers open only after pollination. Due to opening of flower, some cross pollination may occur.
3) In some crops stigma is closely surrounded by anthers and pollination generally occurs when the flowers open e.g. Tomato, Brinjal.

Table : Classification of crop species on the basis of their natural mode of pollination

Self-Pollinated Crop Species (Cross Pollination may occur upto 5%)	
Cereals and Millets	**Vegetables**
Wheat *(Triticum aestivum)*	**Tomato** *(Lycopersicon esculentum)*
Rice *(Oryza sativa)*	**Okra** *(Abelmoschus esculentus)*
Barley *(Hordeum Vulgare)*	Lettuce *(Lactuca sativa)*
Oats *(Avena sativa)*	**Brinjal** *(Solanum melongena)*
Foxtail millet *(Setaria italica)*	**Chillies** *(Capsicum annuum)*
Ragi *(Eleusine coracana)*	Parsnip *(Pastinaca sativa)*
Legumes	**Potato** *(Salanum tuberosum)*
Pea *(Pisum sativum)*	

Groundnut *(Arachis hupogaea)*
Gram *(Cicer arietinum)*
Mung *(Vigna radiata)*
Urd *(Vigna mungo)*
Cowpea *(Vigna anguiculata)*
Soybean *(Glycine max)*
Sem *(Dolichos lablab)*
Lentil *(Lens esculenta)*
Khesari *(Lathyrus sativus)*
Rajma *(Phaseolus vulgaris)*
Guar *(Cyamopsis tetragonoloba)*
Moth *(Phaseolus aconitifolius)*
Sunnhemp *(Crotalaria juncea)*
Fiber Crops
Jute *(Corchorus capsularis)*

Forage crops
Burr clover *(Medicago hispida)*
Subterranean clover *(Trifolium subterraneum)*
Velvet bean *(Mucuna deeringiana)*
Slender wheatgrass *(Agropyron pauciflorum)*
Several other grasses
Oilseeds
Till *(Sesamum indicum)*
Linseed *(Linum ustitatissimum)*
Fruits Trees
Apricot *(Prunus armeniaca)*
Nectarine *(Prunus persica)*
Citrus *(Citrus sp.)*
Peach *(Prunus persica)*

Cross-Pollinated Crop Species
(Self Pollination : 0-20%)

Cereals
Maize *(Zea mays)*
Rye *(Secale cereale)*
Bajra *(Pennisetum americanum)*
Niger *(Guizotia abyssinica)*
Legumes
Alfalfa *(Medicago sativa)*
Red clover *(Trifolium pratense)*
White clover *(Trifolium repens)*
Crimson clover *(Trifolium incarnatum)*
Sweet clover *(Melilotus officinalis)*
Birds foot trefoil *(Lotus corniculatus)*
Vegetables
Cabbage *(Brassica oleracea)*
Carrot *(Daucus carota)*
Cauliflower *(Brassica oleracea)*
Cucumber *(Cucumis sativus)*
Onion *(Allium cepa)*
Pumpkin *(Cucurbita maxima)*
Radish *(Raphanus sativus)*
Turnip *(Brassica rapa)*

Oilseeds
Some strains of *Brassica campestris*
Sunflower *(Helianthus annuus)*
Castor *(Ricinus communis)*
Forage Crops
Ryegrass *(Lolium perenne)*
Timothy grass *(Phleum pratense)*
Smooth bromegrass *(Bromus inermis)*
Johnson grass *(Sorghum halepense)*
Other Crops
Sugarcane *(Saccharum officinarum)*
Some lines of potato *(S.tuberosum)*
Hemp *(Canabis indica)*
Hops *(Humulus lupulus)*
Fruits
Apple *(Pyrus malus)*
Avocado *(Persea americana)*
Mango *(Mangifera indica)*
Pear *(Pyrus communis)*
Blackberries *(Rubus fruticosus)*
Raspberries *(Rubus sp.)*

Muskmelon *(Cucurbita moschata)*	Walnut *(Juglans regia)*
Watermelon *(Cirtullus vulgaris)*	Chestnut *(Castanea sativa and C, vexa)*
Squash *(Cucurbita melanosperma)*	Hazelnut *(Corylus americana and C. cornuta)*
Sweet potato *(Ipomoea batatas)*	**Banana** *(Musa sapientum)*
Other cucurbits *(Cucurbita sp.)*	Cherry *(Prunus avium)*
Beets *(Beta aulgaris)*	Date plam *(Phoenix dactilifera)*
Broccoli *(Brassica oleracea)*	Fig *(Ficus carica)*
Brussels sprouts *(Brassica oleracea)*	**Coconut** *(Cocos nucifera)*
Parsley *(Petroselinum hortense)*	Grapes *(Vitis vinifera)*
Celery *(Apium graveolens)*	**Papaya** *(Carica papaya)*
Spinach *(Spinacea oleracea)*	Plum *(Prunus divaricata)*
Asparagus *(Asparagus officinalis)*	Loquat *(Eriobotrya japonica)*
Garlic *(Allium sativum)*	Strawberries *(Fragaria sp.)*
Coriander *(Coriandrum sativum)*	Almond *(Prunus amygdalus)*
	Pistachio nut *(Pistacia vera)*

Often Cross-Pollinated Crops
(Cross Pollination : 5-30%)

Jowar *(Sorghum bicolor)*	Rai *(Brassica juncea)*
Cotton *(Gossypium sp.)*	*Brassica campestris* var. yellow sarson
Broad bean *(Vicia faba)*	*B. campestris* var. toria (toria)
Jute *(Corchorus olitorius)*	Safflower *(Carthamus tinctorius)*
Tobacco *(Nicotiana tabacum and N. rustica)*	Triticale *(Triticale hexaploide)*
Pigeonpea or arhar *(Cajanus cajan)*	

4) In some species, the flowers open but the stamens and stigma are hidden by the floral organs. e.g. pea, mung, urd, soybean, gram.

5) In few species, the stigma becomes receptive and elongates through the staminal columns.

Self-pollination leads to rise in homozygosity.

Mechanism promoting cross-pollination :

1) **Dicliny or unisexuality** : Dicliny is the name of condition where flowers are either staminate (♂) or pistillate (♀). It is of two types :

a) **Monoecy :** staminate & pistillate flowers are found in the same plant either in the same inflorescence or in

separate inflorescences. Examples of same inflorescence : Castor, Mango, banana & coconut.

Examples of different inflorescences : maize.

b) **dioecy :** Staminate (♂) & pistillate (♀) flowers are found on different plants. e.g. papaya, dates, hemp, asparagus, spinach.

2) **Dichogamy :** Maturity times of stamens and pistils of hermaphrodite flowers are different.

a) **Protogyny :** Here pistils mature earlier than stamens. e.g. bajra

b) **Protoandry :** Here stamens mature earlier than pistils e.g. maize, sugarbeet.

3) In some plants, stigma is covered with a waxy film which is broken by the visit of honey bees facilitating cross pollination e.g. lucerne or alfalfa.

4) More than one mechanisms may occur in some species. e.g. maize has both monoecy and protoandry.

5) **Self Incompatibility :** means the failure of pollen from a flower to fertilize the same flower or other flowers on the same plant. Here male gamete is fully functional. e.g. Brassica sp., Nicotiana, radish etc.

6) **Male Sterility :** means the non-functional pollen grains. Here female gamete is Fully functional. Male sterility is not common in natural populations.

Cross pollination promotes heterozygosity and genetic make up of often cross pollinated plants is intermediate between self-pollinated and cross-pollinated plants.

Self-Incompatibility

Here self-incompatible pollen grain does not germinate and if pollen grain germinates, its pollen tube fails to enter into stigma. If pollen tube enters into stigma and fertilization takes place but ultimately embryo aborts. It means any how embryo does not develope and occurrence of self-incompatibility is due to biochemical reaction but its precise nature is not clearly understood.

On the basis of the interaction between pollen grains and pistil, it is of two types :-

a) Complementary i.e. stimulatory type where pistil & pollen stimulate each other or either. e.g. Dendrobium.

b) Oppositional i.e. inhibitory type where pistil & pollen inhibite each other or either. Almost all the cases of self incompatability are inhibitory type.

Lewis (1954) suggested various types of classifications of self-incompatability (SI). A simpler classification is-

1) **Heteromorphic System** : Flowers of different incompatibility groups are different in morphology.

$\underbrace{\text{Hetero}}_{\text{different}}\ \underbrace{\text{morphic}}_{\text{morphology}}$

The compatibility reaction of pollen is determined by the genotype of the plant producing them. The incompatibility system is heteromorphic-sporophytic.

2) **Homomorphic System** : Here morphological differences between flowers is not associated with incompatibility. The incompatibility reaction of pollen is either controlled by the genotype of the plant on which it is produced (sporophytic control) or by its own genotype (gametophytic control).

Gametophytic system : East and Mangelsdorf (1925) firstly discribed Gametophytic incompatibility in *Nicotiana sanderae*. The incompatibility reaction of pollen is determined by its own genotype and not by the genotype of the plant on which it is produced. e.g. pineapple, ryegrass, diploid coffee, diploid clovers (*Trifolium* sp.) etc.

Sporophytic system : First time this system was reported by Hughes & Babcock (1950) in *Crepis foetida* and by Gerstel (1950) in *Parthenium argentatum*. The incompatibility reaction of pollen is determined by the genotype of the plant on which the pollen is produced and not by the genotype of the pollen.

Elimination of self-incompatibility :

By i) doubling the chromosome number in single locus gametophytic system.

ii) isolation of self-fertile mutations (very useful tool)

iii) the transfer of self-compatibility alleles from a related species through a back cross programme.

Temporary suppression of self-incompatibility :

For the production of inbred (for hybrid seed production) it is essential to achieve self-fertility, where self-incompatibility is fully functional in the selfed progeny. This self-fertility is called as pseudofertility. This pseudofertility is achieved through temporary suppression of incompatibility by one of the following techniques :-

i) **Bud pollination :** means application of mature pollen to immature non-receptive stigma generally 1-2 days before anthesis. Bud pollination is the **most practicable & successful** method in both gametophytic and sporophytic systems.

ii) Surgical techniques : Removal of stigma is very useful in sporophytic system. Pollen is directly dropped on to the ovules.

iii) End-of-season pollination : controversial technique.

iv) High temperature : may induce pseudo fertility e.g. in Trifolium, Lycopersicon, Brassica, Oenothera exposure of pistils upto 60^0C induces pseudo fertility.

v) Increased CO_2 conc. in sporophytic system.

vi) High humidity.

vii) Salt (NaCl) sprays are used by the Chinese.

viii) Irradiation : in a single locus gametophytic system. e.g. in solanaceae, acute irradiation with x-rays or r-rays induces pseudo-fertility.

ix) Grafting.

x) Double pollination.

xi) other techniques like use of phytohormones, treatment of flowers with carbon-monoxide etc.

Male Sterility

Male sterility means non-functional pollen grains. Here female gametes are normally functional. It is classified into four groups :-

1) Genetic male sterility (GMS) or Nuclear male sterility
   - Temperature-sensitive GMS
   - Photoperiod-sensitive GMS
   - Transgenic GMS
2) Cytoplasmic male sterility (CMS)
3) Cytoplasmic-genetic male sterility (CGMS)
4) Chemically-induced male sterility.

Genetic (Nuclear) Male Sterility : GMS/NMS is ordinarily governed by a single recessive gene ms but also by dominant genes. Male sterility alleles are occurred spontaneously or are induced artificially.

When a male sterile plant (msms) is crossed with the male fertile (Ms Ms) plant, the product F_1 (Msms) is male fertile. In F_2, 3 Fertile : 1 sterile is obtained. A male sterile line is maintained by crossing with heterozygous male fertile (Ms ms). This mating produces 1:1 male sterile & male fertile plants.

ms ms (male sterile) × Ms Ms (male fertile)

↓

F_1 Ms ms (male fertile)

↓

F_2 1 MsMs, 2Msms, 1 ms ms 3:1

Male fertile (1 MsMs, 2Msms); Male sterile (1 ms ms)

Maintenance of a male sterile line :-

♀ ms ms male sterile line A × ♂ Ms ms F_1 male fertile (F_1 is backcrossed with the male sterile line A)

↓

Ms ms ♂ male fertile (Seed not harvested) × ms ms ♀ male sterile (Seed harvested) (Sib-mating)

↓

Ms ms ♂ male Fertile (seed not harvested) × ms ms ♀ (sib mating) male sterile (Seed harvested)

↓

maintained indefinitely

During the maintenance of male sterile lines, sibmating (i.e brother-sister mating) is achieved through natural pollination.

In some cases ms gene expression is affected by the specified range of temperature and or photoperiod regime. Such GMS is environment sensitive and found in Rice, tomato, wheat etc.

Temperature-sensitive Genetic Male sterility : (T GMS) Complete male sterility is produced by the ms gene at higher temperatures e.g. 23.3^{0}C or higher for rice TGMS line Pei-Ai 645. This type of genetic male sterility is being used in the **China** to develop **hybrid rice.**

Photoperiod-sensitive Genetic male sterility (PGMS) : In some cases, ms gene expression is drastically affected by the prevailing photoperiod, provided the temp. is within the critical range. e.g. the critical temp. is 23-29^0 C for rice for PGMS. Within this critical temp. range, complete sterility is found in rice plants grown under long day conditions (i.e day length more than 13 hours 45 minutes). But under short day conditions almost normal fertility is found. This type PGMS is being utilised in the **China** to develop hybrid rice.

Transgenic Genetic male sterility : Transgene is a such gene which is introduced into the genome of an organisms by recombinant DNA technology or genetic engineering. Many trangenes cause male sterility. These are found in maize, cauliflower, tomato, wheat & chicory but this system is not yet used commercially.

The genetic male sterility is being used for hybrid rice development in China. GMS is being successfully used in castor in U.S.A. In India GSM is being used for hybrid seed production of Arhar by private companies like Maharashtra Hybrid seed Co. Ltd.

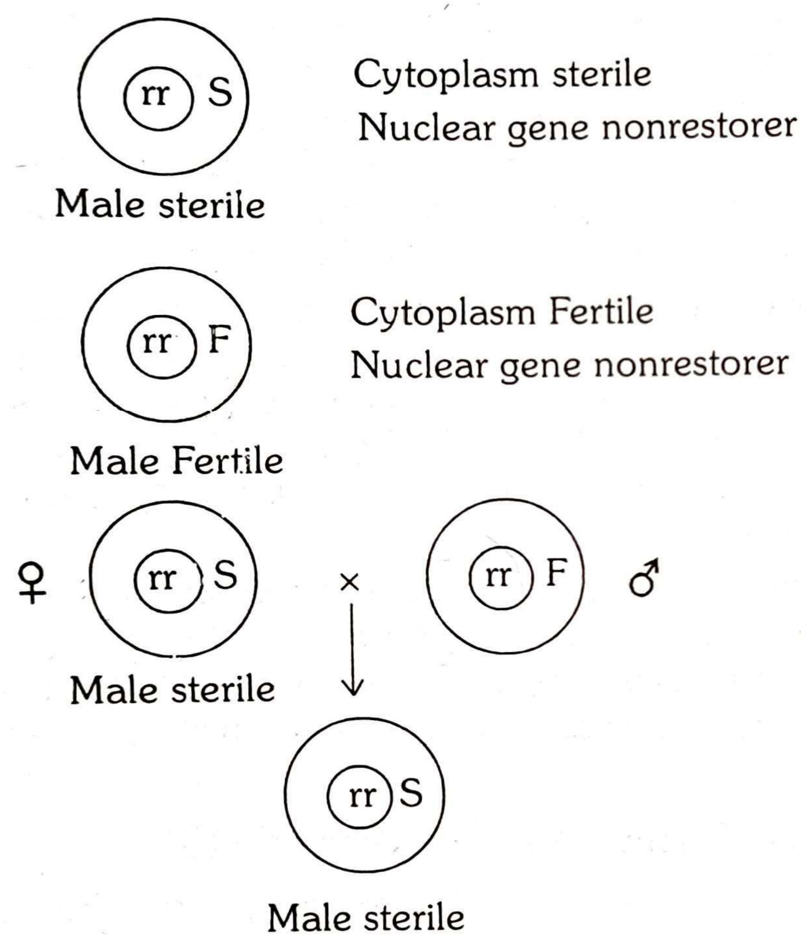
Cytoplasmic Male Sterility (CMS)

Here male sterility is governed by the cytoplasm. The male sterility is the result of mutation in the mitochondrial genome (mt DNA) which leads to mitochondrial dysfunction e.g. cms-T of maize, Ogura cms of brassica.

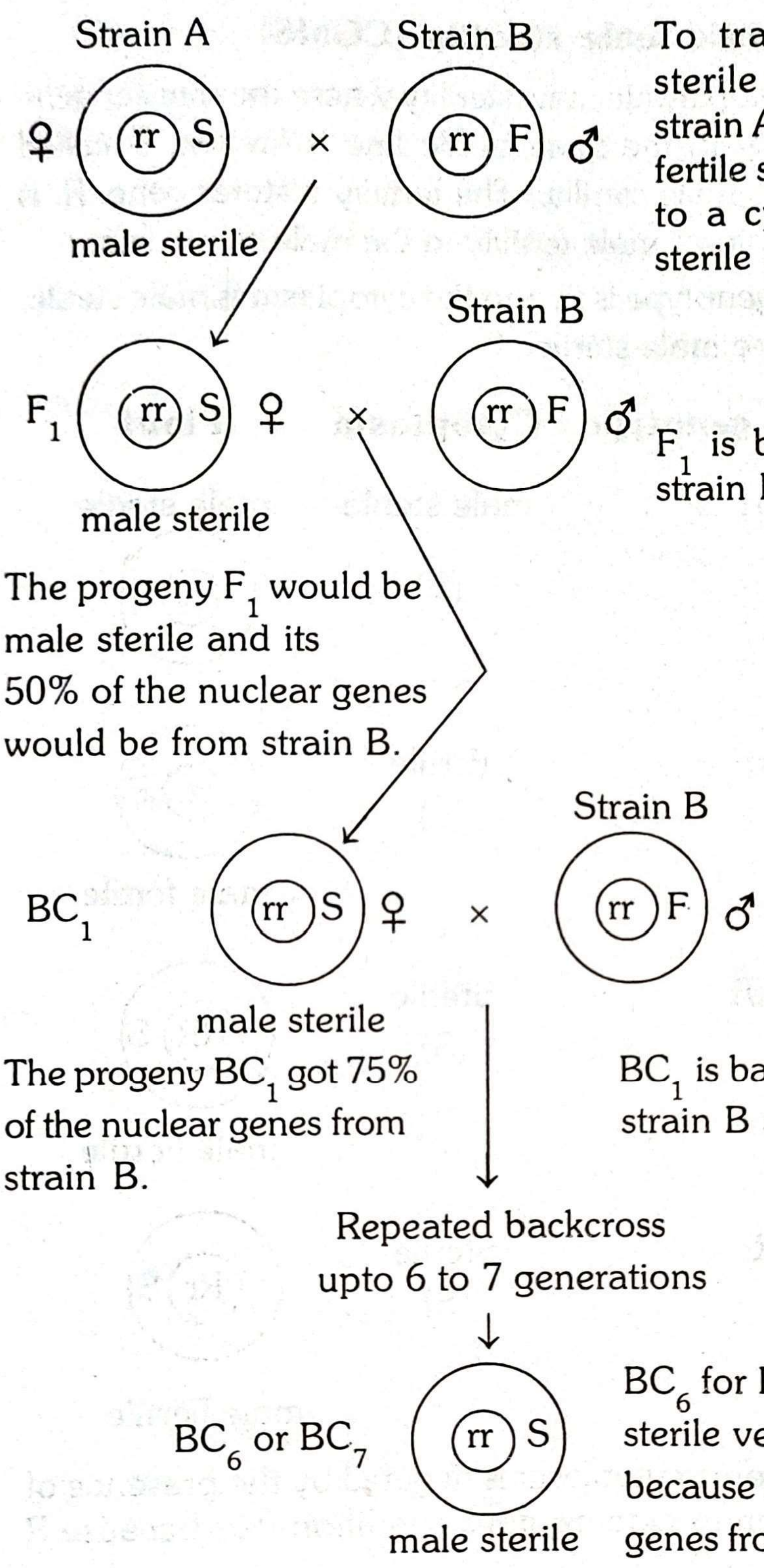
Since the cytoplasm of a zygote comes primarily from egg cells, the progeny of such male sterile plants would always be male sterile. Cytoplasmic male sterility may be transferred easily to a given strain by using that strain as a pollinator (recurrent parent) in the successive generations of a backcross programme.

CMS is used only for the vegetative growth purposes because all the progenies are male steriles & there are no seed setting. It is used in chillies by some private companies.

In 1996, Kaul concluded that restorer genes have been detected for all cases of CMS. The idea of CMS has been disfavoured by Kaul and according to Kaul, male sterility is either genetic or cytoplasmic-genetic.



Male sterility is caused by the cytoplasm.



To transfer the male sterile cytoplasm from strain A to strain B; Male fertile strain B is crossed to a cytoplasmic male sterile strain A.

F_1 is backcrossed with strain B as a male.

The progeny F_1 would be male sterile and its 50% of the nuclear genes would be from strain B.

The progeny BC_1 got 75% of the nuclear genes from strain B.

BC_1 is backcrossed with strain B as a male.

BC_6 for BC_7 is the male sterile version of strain B because it got 99% nuclear genes from strain B. Strain B is served as maintainer line of this new male sterile strain.

Cytoplasmic-genetic male sterility (CGMS)

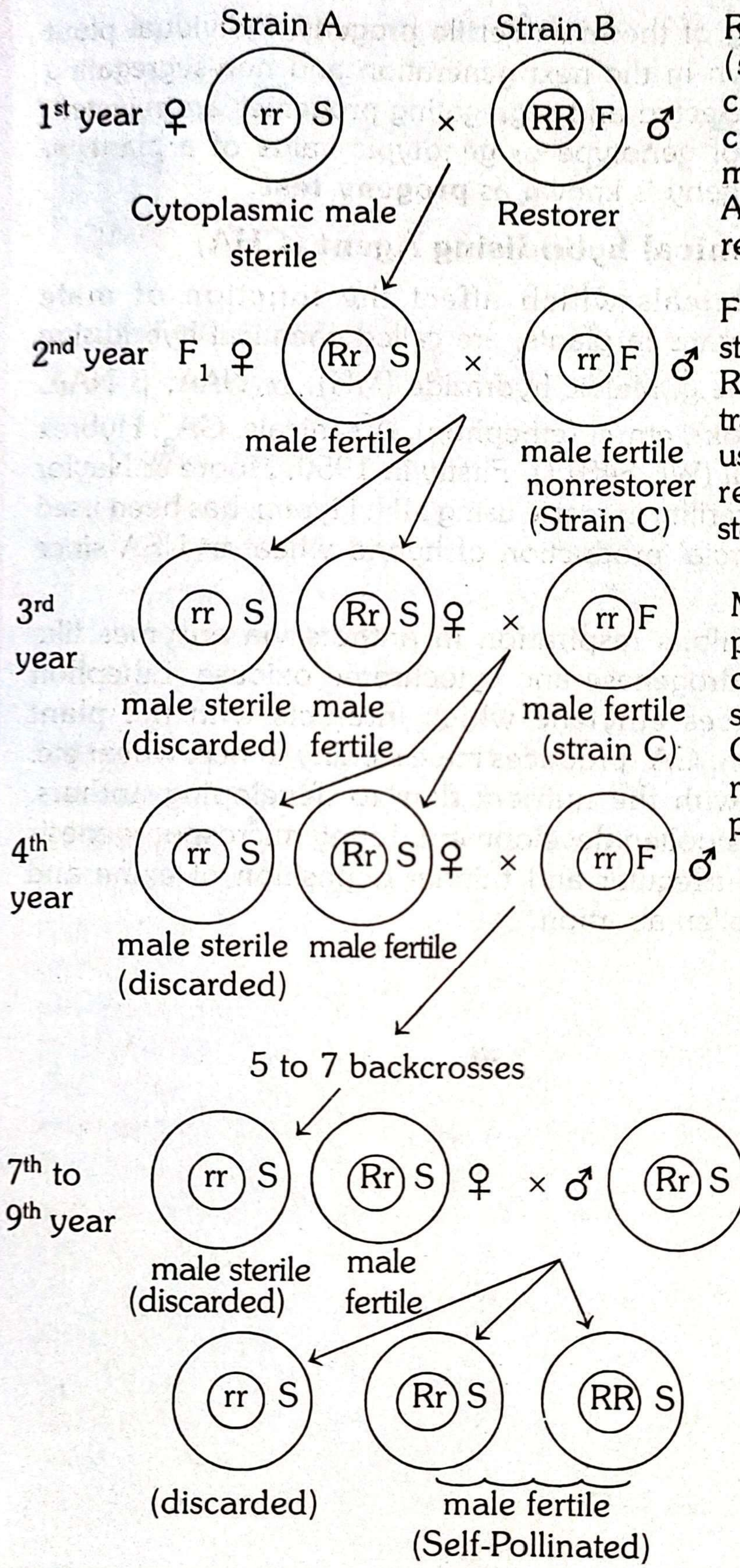
The case of cytoplasmic male sterility where the nuclear gene for restoring fertility in the male sterile line is known; is called cytoplasmic genetic male sterility. The fertility restorer gene, R, is dominant which restores male fertility in the male sterile line.

If the nuclear genotype is rr, and the cytoplasm is male sterile, then plant would be male sterile.

S.No.	Nuclear genotype	Cytoplasm	Plant
1.	rr	male sterile (S)	male sterile rr S
2.	rr	Fertile (F)	rr F male fertile
3.	RR	Sterile (S)	RR S male Fertile
4.	Rr	Sterile (S)	Rr S male Fertile

The effect of sterile cytoplasm is negated by the presence of restorer gene R even in heterozygous condition (Rr) because R is dominant over r.

C GMS is also known as nucleoplasmatic male sterility. CGMS is commercially utilized in maize, cotton, Jowar, bajra, sunflower, rice, wheat etc.



Restorer line R (strain B) is crossed to a cytoplasmic male sterile line A to transfer restorer gene R.

F_1 is crossed to strain c in which R gene is to be transferred. F_1 is used as female to retain male sterile cytoplasm.

Male fertile progeny is back crossed to strain C. strain C is used as recurrent male parent.

Selfing of male fertile progeny

After selfing of the male Fertile progeny, individual plant progeny is grown in the next generation and non-segregating progenies are selected and segregating progenies are rejected. Determination of genotype or genotypic value of a plant by studying its progeny is known as **progeny test.**

Chemical hybridising Agent (CHA)

Such chemicals which affect the function of male reproductive organs in plants; are called chemical hybridising agents (CHAs). e.g. Maleic hydrazide (MH), α-NAA, β-NAA, FW 450 (Mendok), ethrel (ethephon), Arsenicals, GA_3, Hybrex (RH0007), Shell (WL 84811). Firstly in 1950, Moore & Naylor induced male sterility in maize using MH. Hybrex has been used for the commercial production of hybrid wheat in USA since 1982.

Arsenic inhibits respiration in anthers via enzymes like succinate dehydrogenase and cytochrome oxidase. Ethephon (Ethrel) produces ethylene which interacts with the plant hormone system. GA_3 produces male sterility in rice, wheat etc. by interfering with the nutrient flow to developing anthers. Hybrex disrupts pollen development during microsporogenesis which leads to irregular and thinner deposition of exine and ultimately to pollen abortion.

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30 Qualitative & Quantitative Characters

Basic requirements of Plant breeding :

a) Variation in a character = It is must for the improvement in the character. Variation may be created by hybridization, mutation or polyploidy.

b) Selection means identification and isolation of diserable plants. Selection from a population depends on the appearance i.e. phenotype. Phenotype may be heritable or may not be. Heritable character of phenotype is due to genotype i.e. genes present in the plants.

Genes do not produce characters directly. Genes produce different proteins which often acts as enzymes. Enzymes catalyse a specific biochemical reaction which finally leads to development of various characters i.e. phenotype.

Some characters are little affected by other genes i.e..the genetic background, or the environment. Such characters are generally governed by one or few genes with large easily detectable effects. These genes are called oligogenes. Oligogenes produce the characters having distinct classes. These characters are called qualitative characters. In other words **Qualitative characters** are such characters which show distinct classes, are little affected by the environment (both external and internal), and are governed by one or few genes with large distinct effects i.e. oligogenes.

Whereas most of the characters are governed by several genes with individual effects and very much affected by the genetic background and more particularly by the environment. These genes are called polygenes. The characters produced by polygenes do not show clear-cut classes and have to be studied by measurement, are called **Quantitative Characters.** In

other words, the quantitative characters show continuous distribution, are generally influenced by the environment and are controlled by several genes with small and cumulative effects i.e. polygenes. The small effect of each gene is usually cumulative. Examples yield, plant height, days to flower, days to maturity, protein content, seed size etc.

Inheritance of both characters i.e. qualitative and quantitative follows the laws of Mendel but the effects of individual genes are totally different. Mendel proposed his laws of inheritance based on his studies with qualitative characters.

Pleiotropy :

A single major gene i.e. oligogene generally governs a single character but there are many instances where an oligogene affects more than one character. Such phenomenon of a single major gene affecting more than one character is known as pleiotropy and such a gene action is called pleiotropic gene action.

Clearcut examples of pleiotropy are but limited mainly because of difficulty in demonstrating pleiotropic effect of a gene. To investigate pleiotropic effect of a gene, two lines must be developed which are identical with respect to all other genes except for the gene under investigation. Such lines are called **isogenic lines.**

Penetrance & Expressivity :

Generally the expression of oligogenes is fairly uniform but some oligogenes fail to express themselves in some of the individuals carrying them. Such genes have incomplete penetrance.

Penetrance is the ability of a gene to express itself in the individual carrying it in the appropiate genotype. e.g. a gene that causes partial chlorophyll deficiency in the cotyledonary leaves of lima beans *(Phaseolus lunatus)*. But only about 10% of the seedlings carrying such gene show chlorophyll deficiency. It means such gene has 10% penetrance i.e. it expresses itself in 10% of the individuals carrying it.

On the other hand, the gene which expresses itself in every individual that carries it is said to have a complete penetrance.

In contrast, some oligogenes show variable degree of expression in different individuals having the appropriate genotype for this gene. Such genes have variable expressivity. Expressivity is the ability of gene to express itself uniformly in all the individuals that carry it. A gene which expresses itself uniformly in all the individuals has uniform expressivity, while those that are unable to do so have variable expressivity.

Incomplete penetrance and variable expressivity confuse the relationship between genotype and phenotype. In such cases, progeny tests for more than one generation may be required to establish the genotype of the plants.

Threshold characters : Certain genes require a specific environment for their expression, such characters are called threshold characters. e.g. a mutant gene in barley *(Hordeum vulgare)* produces albino seedlings at temperatures below 8^0C.

Modifying genes : The genes modify the effects of other genes are called modifying genes. Such genes have no any effect of their own but they increase or decrease the expression of other oligogenes. The effects of such genes are quantitative in nature. e.g. spotting in mice is affected by modifying genes.

Gene interaction :

Many qualitative characters are controlled by two or more oligogenes which interact in various ways.

Complimentary gene action (9:7) : In japanese varieties of rice *(O. sativa)*, two dominant genes Rc and Rd are needed to produce red pericarp. When one of the two genes or both the genes are in the recessive state, the pericarp is white. Such gene interaction is called complimentary gene action which shows 9 : 7 ratio in F_2.

Supplementary gene action (9:3:4) : In maize (*Zea mays*), a gene Pr has no effect of its own but Pr modifies the action of the gene R. Gene R produces red colour. In presence of R, Pr changes the red colour to purple. Such type of gene interaction is called supplementary gene action which produces 9:3:4 ratio in F_2.

Inhibitory gene action (13:3) :

Some gene stops the action of another gene but has no

effects of its own. Red colour production in maize is stopped by an inhibitory gene I. The recessive allele i is not inhibitory. Such inhibitory gene action shows 13:3 ratio in F_2.

Epistatic gene action (12:3:1)/masking gene action): In barley (*Hordeum vulgare*) a dominant gene Y produces yellow seed coat while another gene B produces black seed coat. When genes Y & B are together, the effect of Y is masked by B and yellow seed coat is not seen. Epistasis is generally used to denote interaction between two nonallelic genes. It shows 12 : 3 : 1 ratio in F_2.

Duplicate gene action (15 :1) :

Some characters are governed by two genes which produce identical effects, whether together or alone. The alternative characters result only when both genes are in recessive form. Such interaction is known as duplicate gene action whose ratio in F_2 is 15 : 1.

Polymeric gene action (9 : 6 : 1) : In polymeric gene action, two genes produce identical effects individually but their effect is increased when both genes are present together. The ratio in F_2 is 9 : 6 : 1 e.g. in barley gene A or B alone produces awns of medium length but presence of both A & B produces long awn.

Quantitative Characters

In 1906, Yule suggested that many genes with small, similar effects could produce continuous variation. He proposed that these genes (responsible for quantitative characters) were transmitted according to the laws of Mendel. In 1908. Nilsson-Ehle presented experimental evidence to support the hypothesis of Yule i.e. seed colour in wheat and oat. The F_2 generations from various crosses had red & white grains in the ratios of 3 : 1, 15 : 1 or 63:1. It means that the seed colour in these crosses were governed by one, two and three genes respectively. The closer study of seed colour in 15:1 ratio revealed that the seed classified as red differed in the intensity of colour. Thus it was assumed that the seed colour was governed by two genes with similar, small and additive effects and Nilsson-Ehle showed that

certain characters were governed by genes which have small & cumulative effects.

This is known as *multiple factor hypothesis or polygenic inheritance.*

East in 1916 presented conclusive evidence by studying inheritance of corolla length in *Nicotiana longiflora* that quantitative characters are governed by many genes with small & cumulative effects. To analyse his data, East used statistical parameters such as frequency distribution, mean & coefficient of variability.

Quantitative characters are considerably affected by the environment i.e. 10-50%. The chief effect of environment is to mask the differences between different genotypes and to produce a continuous variation even if the no. of governing genes is very small or even one.

Assuming the effect of environment is zero, the increase in no. of governing genes produces a smimilar continuous variation. It means polygenic inheritance produces continuous variation.

Due to the environmental effect or polygenic inheritance, phenotype does not reveal the genotype. The phenotype may be described in a mathematical model :-

$\overline{X} = \mu + g + e + ge$ Where $\overline{X}$ = phenotypic mean

μ = general population mean (i.e. phenotype of all possible genotypes grown under all possible environments)

g = effect of genotype

e = effect of environment

ge = interaction between genotype & environment

genotype x environment : signifies the various genotypes affected by environment.

Variance due to environment may be estimated from a replicated trial consisting of several genotypes. But the interaction component may be estimated only when the trial is conducted in more than one environment, preferably at different

locations and during different years. From such a trial the genetic variance and phenotypic variance can be computed which may be used to estimate heritability.

$$\text{Phenotypic variance } (\sigma^2 p) = \text{genotypic variance } (\sigma^2 g) + \text{environmental variance } (\sigma^2 e)$$

In crop improvement, only the genetic component of variation is important. The ratio of genetic variance to the total variance i.e. phenotypic variance is called heritability.

$$\text{Heritability (H)} = \frac{V_g}{V_p} = \frac{\text{genetic variance}}{\text{phenotypic variance}}$$

$$= \frac{V_g}{V_g + V_e} \text{ Where } V_e = \text{environmental variance.}$$

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31 Selection in Self-pollinated Crops

Selection is essentially based on phenotype of the plants. The effectiveness of selection primarily depends upon the degree to which the phenotype reflects the genotype.

Basic characteristics of selection :-

(1) Selection is effective only for heritable differences.

(2) Selection does not create new variation.

It means there are two requirements of selection :-

(1) Variation must be present in the population.

(2) Variation must be heritable.

Purpose of selection : to isolate desirable plant types from the population.

Two basic steps of any breeding programme :-

(1) Creation of variation.

(2) Selection.

Progeny test : The value of the plant is judged by the performance of its progeny. Evaluation of the plant on the basis of performation of its progeny is known as progeny test. This test was developed by Louis de Vilmorin. Therefore it is also known as Vilmorin principle or Vilmorin Isolation Principle.

According to Vilmorin : The real value of a plant can be known only by studying the progeny produced by it.

Two valuable functions of progeny test :

(1) to determine the breeding behaviour of a plant i.e. whether the plant is homozygous or heterozygous.

(2) to find out whether the character for which the plant was selected is heritable. This is the most important function.

Pureline Theory :

A pureline is the progeny of a single homozygous plant of a self-pollinated species.

A pureline is a progeny of a single homozygous, self-pollinated plant.

All the plants in a pureline have the same genotype. It means the phenotypic differences within a pureline are due to environment and the variation within a pureline is not heritable.

The concept of the pureline was given by **Johannsen** in 1903 on the basis of his studies with the Princess variety of beans (*Phaseolus vulgaris*). Johannsen brought commercial seed lot of the Princess variety of beans and found that the seed lot had variation in seed size. He selected the seed of different sizes and grew them separately. The obtained progenies differed in seed size i.e. large seeds were obtained from larger seeds and smaller seeds from smaller seed. It means that the variation in seed size in commercial seed lot had genetic base and selection for seed size was effective. Johannsen further studied 19 lines i.e. each line was a progeny of a single seed from the original seed lot. He found that variation in seed weight in each 19 line was much smaller than that in original seed lot. Ultimately he postulated that the original seed lot was a mixture of purelines means each of 19 lines was a pureline and variation in seed size within each of the purelines had no genetic basis and was purely due to environment.

Conclusions of Johannsen's experiment.

(1) A self fertilized population consists of a mixture of several homozygous genotypes. Here selection is effective because variation in such population has a genetic basis.

(2) Selection within a pureline is ineffective because variation within purelines is purely environmental.

Effects of self-pollination :

Self pollination increases homozygosity.

Self pollination decreases heterozygosity.

Inbreeding : mating between individuals related by descent i.e. having a common parent or parents is called inbreeding.

Sibmating means brother-sister mating. Half sibmating means brother-stepsister mating. Self-pollination is the most intense form of inbreeding.

Homozygosity (i.e. frequency of genes in homozygous condition in the population) = Frequency of homozygotes =

$$= \frac{2\left(2^{n-1}\right)}{2^{n+1}} = \frac{2^{n-1}}{2^n}$$ where n : number of generations of self fertilization.

Frequency of heterozygotes i.e. heterozygosity =

$$= \frac{2}{2^{n+1}} = \frac{1}{2^n}$$

Here homozyogosity is not affected by the number of segregating genes, and also by the linkage.

In a case of single gene, the frequency of homozygous plants in a generation is the same as the proportion of homozygosity. But when two or more genes are segregating, the proportion of homozygosity increases at a much faster rate than that of completely homozygous plants.

The proportion of completely homozygous plants :

$$= \left[\frac{2^m - 1}{2^m}\right]^n$$ where m : no. of generations of self-pollination

n : no. of segregating genes

When the no. of segregating genes increases the proportion of completely homozygous plants decreases. But selfing (Self-pollination) is so strong that even if 100 genes are segregating, more than 95% of population would be completely homozygous after only 12 generations.

Main effects of Selfing :-

(1) All the plants in the population become completely homozygous.

(2) Population is a mixture of several homozygous genotypes.

Pureline Selection : Here a large no. (i.e. 200-3000 plants) of plants are selected on the basis of their phenotype

from a self pollinated plant and are harvested individually. Their individual progenies are evaluated and are grown. Undesirable progenies are rejected. Upto seventh year this process may be maintained if necessary. Ultimately the best progeny is selected and released as a pureline variety. Here individual plant is selected, therefore pureline selection is also known as **individual plant selection.**

Pureline selection is the most commonly used method of improvement of self-pollinated crops. Almost all the present varietes of self-pollinated crops are **purelines.**

Characteristics of a pureline :

(1) All the plants within a pureline have the same genotype.

(2) The variation within a pureline is environmental and non-heritable.

(3) Purelines become genetically variable with time due to mechanical mixture, natural hybridization, chromosomal aberrations & mutation.

Mass-Selection : Here a large no. of plants (i.e 200-2000 plants) of similar phenotype (i.e. phenotypically superior) are selected and their seeds are mixed together to constitute a new variety. The variety developed through mass selection would have considerable genetic variation.

Generally plants selected in mass selection are not subjected to progeny test but according to Allard (1960) progeny test should be done.

In self pollinated crops, mass selection has two major applications-

(1) Improvement of Desi or local varieties.

(2) Purification of existing pureline varieties.

In cross pollinated crops through mass selection, inbreeding is avoided or kept to minimum because in mass selection several plants are selected and their seeds are mixed to raise the next generation.

Due to popularity of pureline varieties, mass selection is not commonly used in improvement of self-pollinated crops.

At present use of mass selection is limited to purification of pureline varieties of self-pollinated crops.

Pureline selection and Mass selection are used in selecting new varieties from mixed populations that have homozygous plants. These selections can not be applied to segregating populations e.g. F_2, F_3 etc. obtained from crosses.

The **methods generally used in handling the segregating generations** are :-

(a) pedigree method
(b) bulk method
(c) backcross method.

The objective of the above three methods is to develop pureline varieties.

(a) Pedigree method : Here individual plants are selected from F_2 and subsequent generations. Their progenies are tested during the entire operation and a record of all the parent-offspring (progeny) relationships is kept. Individual plant selection is continued till the progenies show no segregation. Pedigree means a description of the ancestors of an individual.

Pedigree method is the most commonly used method for selection from the segregating generations from crosses in self pollinated crops. This method is often used to correct some specific weakness of an established variety (i.e. combination breeding).

Pedigree method provides the best opportunity for the breeder to exercise his skill in selection.

(b) Bulk method : This method was first used by Nilsson-Ehle in 1908 at Svalof. This method is also known as mass method or the population method of breeding.

Here F_2 and subsequent generations are harvested in mass or as bulks to raise the next generation. At the end of the bulking period, individual plants are selected and evaluated in a similar manner as in pedigree method. In pedigree method individual plant progenies are grown and evaluated in F_3 and subsequent generations but in bulk method these generations are grown as bulks.

Purpose of bulk method :-

i) isolation of homozygous lines with a minimum effort & expense.

ii) Waiting for opportunity of selection. Selection for resistance, lodging etc. depends upon the presence of suitable environmental conditions favouring disease epidemic, severe lodging etc. Such environment do not occur every year.

The segregating generations may be carried in bulk until such environments occur.

iii) Opportunity for natural selection : Some bulk populations may be carried upto F_{20} or F_{30} to provide opportunity for natural selection to act. It was called evolutionary method of breeding by Suneson.

C) Backcross method : Backcross is a cross between a hybrid (F_1 or a segregating generation) and one of its parent. In this method, the hybrid and the progenies in the subsequent generations are repeatedly back crossed to one of the parent. At the end of 6-8 backcrosses, the progeny would be almost identical with the parent used in backcross.

Objective of backcross : to improve one or two specific defects of a high yielding variety.

The characters lacking in the variety are transfered to it from a donor parent without changing its genotype except for the gene (genes) being transferred.

Since recipient parent is repeatedly used in backcross, recipient parent is also known as recurrent parent and the donor parent is known as non-recurrent parent because it is used only once for producing the F_1 hybrid.

Backcross method changes the genotype of the recurrent parent only for the gene under transfer. It is the only useful method for gene transfers from related species and for producing addition and substitution lines. It is suitable for transfer of both qualitative and quantitative charaters provided they have moderate to high heritability.

The objective of pure line selection, pedigree method, bulk method and backcross method is to develop pure line varieties. These methods either use the variability present in the population (mass selection & pure line selection) or the variability created through hybridization.

The F_1 hybrid from a cross is either allowed to self-pollinate (pedigree and bulk method) or is backcrossed to the desirable parent (backcross method).

The effect of either of the above approaches is a rapid increase in homozygosity.

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32 Selection in Cross-pollinated Crops

Cross pollinated crops are highly heterozygous due to free intermating of plants. Such crops are called **random mating** populations due to equal opportunity of mating in each individual. Random mating population is also called **Mendelian population** or **Panmictic population.**

To understand the genetic make-up of such population we need population genetics.

Fundamental law of population genetics is the **Hardy-Weinberg law** which provides the basis to study mendelian populations. This law was independently developed by Hardy (1908) in England and Weinberg (1909) in Germany.

According to Hardy-Weinberg law :- "The gene and genotype frequencies in a Mendelian population remain constant generation after generation if there is no selection, mutation, migration or random drift".

The frequencies of the three genotypes for a locus with two alleles (ie. A & a) i.e genotypic frequency or zygotic frequency (genotypic/zygotic frequency is the proportion of a genotype AA, Aa or aa in the population)

= p^2 AA, 2 pq Aa, q^2aa

where p is the gene frequency of A

q is the gene frequency of a

the sum of p and q is one i.e.

$$p + q = 1$$

gene frequency is the proportion of an allele A or a in the population i.e. proportion of gametes carrying an allele A or a)

Such a population would be at equilibrium since genotypic frequencies would be stable i.e. would not change from one generation to the next. This equilibrium is called Hardy-

Weinberg equilibrium A population is said to be at equilibrium when the frequencies of three genotypes AA, Aa & aa are p^2, 2 pq and q^2 respectively, whether a population is at equilibrium or not can be easily determined by a chi-square test.

Terms in Hardy-Weinberg law :-

Selection : Differential reproduction of genotypes is known as selection. Selection allows the selected genotypes to reproduce while undesirable genotypes are eliminated. Selection in a random mating population is highly effective in increasing or decreasing the frequency of alleles but it is unable to either fix or eliminate them.

Mutation : is a sudden and heritable change in an organism and is generally due to a structural change in a gene. Mutation is the ultimate source of all the variation present in the biological materials. Mutation may produce a new allele not present in the population or may change the frequencies of the existing alleles.

Migration : is the movement of individuals into a population from a different population.

Random drift/Genetic drift : is a random change in gene frequency due to sampling error. Random drift occurs in small populations due to greater sampling error.

Inbreeding : is the mating between individuals sharing a common parent in their ancestory.

Selection in cross-pollinated species :

a) increases the frequency of desirable alleles and genotypes.

b) leads to production of new genotypes.

c) changes the mean in the direction of selection.

d) may or may not reduce genetic variance.

Five different types of responses to selection :

i) Rapid gain followed by a period of slow gain is seen in characters governed by few major genes and several minor genes.

ii) Slow gain for a long time is the characteristic of traits governed by polygenes. The contribution of each gene is small but the haritability is high.

iii) Slow gain ending in a plateau, is found in such quantitative characters where the change due to selection beyond a limit is prevented by physiological limitations.

iv) No gain or little gain in such quantitative characters which have low heritability e.g. yield. The failure of selection is primarily due to low heritability.

v) Rapid gain - plateau - rapid gain, results from release of potential variability.

Inbreeding Depression & Heterosis

Cross pollinated species and species reproducing asexually are highly heterozygous. Due to inbreeding such species generally show severe reduction in fertility and vigour. This is called inbreeding depression. On the other hand, hybridization between unrelated strains generally leads to increased vigour & fertility. This is known as **Hybrid Vigour (heterosis).**

Inbreeding Depression:

Inbreeding is the mating between individuals related by descent or ancestory. The highest degree of inbreeding is achieved by selfing. The main effect of inbreeding is an increase in homozygosity in the progeny.

The reduction or loss in vigour and fertility due to inbreeding is known as inbreeding depression.

In 1876, Darwin in his book 'Cross and self fertilization in vegetable kingdom' concluded that progeny obtained from self-fertilization were weaker than those derived from out crossing.

Detailed and precise information on inbreeding (in maize) was published independently by East in 1908 and Shull in 1909. Self-pollinated species do not show inbreeding depression, although they do show heterosis. Heterosis is observed in both cross pollinated and self pollinated species.

Some species, onion, cucurbits etc. show little or no inbreeding depression; in species like maize & bajra there is

moderate inbreeding depression, while in some species such as alfalfa & carrot, the inbreeding depression is very severe.

Effects of Inbreeding :

1) appearance of lethal and sublethal alleles.
2) reduction in vigour
3) reduction in reproductive ability.
4) separation of the population in distinct lines. The population rapidly separates into phenotypically distinct lines.
5) increase in homozygosity.
6) reduction in yield.

Inbred lines : Due to continued inbreeding after 7 to 8 generations, the lines become almost uniform (> 99% homozygosity) which are maintained through close inbreeding, such lines are called inbred lines.

Heterosis/Hybrid Vigour

The term 'heterosis' was first used by Shull in 1914.

Heterosis is the superiority of F_1 hybrid over both the parents in terms of yield or some other character.

Often the superiority of F_1 is estimated over the average of the two parents, or the mid-parent. If the hybrid is superior to the mid-parent, it is known as **average heterosis** or simply **heterosis.** Average heterosis is of little or no use for the plant breeder. More Generally, heterosis is estimated over the superior parent, such estimate is sometimes known as **heterobeltiosis.**

In many cases, the superior parent of the hybrid is likely to be inferior to the best commercial variety. In such cases, heterosis is only estimated in relation to the best commercial variety. This estimate is known as **economic** or **useful heterosis.**

Hybrid vigour is the synonym of heterosis but hybrid vigour describes only superiority of the hybrids over the parents while heterosis describes other situations as well.

When F_1 hybrid is inferior to parents, then it may be called hybrid vigour in negative direction e.g. many F_1 hybrids in tomato are earlier than the parents.

Hybrid vigour was first time reported by **Koelreuter** in artificial tobacco (*Nicotiana sp.*) hybrids in 1673. Darwin in 1876 concluded that hybrids from unrelated plants are highly vigorous.

Later on **maize** became most extensively studied crop with respect to heterosis and inbreeding depression.

According to **Power** (1944) the term heterosis should be used only when the hybrid is either superior or inferior to both the parents. Other situations should be regarded as partial or complete dominance.

The magnitude of heterosis in self-pollinated species is generally smaller than that of cross pollinated species. The main draw back in use of hybrid varieties in self pollinated crops is the production of less quantity of hybrid seed. Hybrid varieties are commercially used in tomato because a single fruit produces a large number of seeds.

Luxuriance : Luxuriance is the increased vigour and size of inter-specific hybrids. The main difference between heterosis and luxuriance lies in the reproductive ability of the hybrids. In heterosis there is increased fertility whereas in luxuriance there is generally sterility or poor fertility.

Genetic Basis of Heterosis & Inbreeding Depression :

Heterosis and inbreeding depression are the two opposite sides of the same coin. There are three main theories to explain heterosis & inbreeding depression-

[A] Dominance hypothesis : This hypothesis was first proposed by Davenport in 1908 and was later explained by Bruce, Keeble and Pellew in 1910. According to Dominance hypothesis, in heterozygous condition, the deleterious effects of the recessive alleles are masked by their dominant alleles i.e. heterosis is produced from masking of harmful effects of recessive alleles by their dominant alleles and Inbreeding depression is produced by harmful effects of recessive alleles which becomes homozygous due to inbreeding.

It means heterosis is not the result of heterozygosity but the result of prevention of the expression of harmful recessives by their dominant alleles. Similarly inbreeding depression is not

the result of homozygosity but from homozygosity of recessive alleles which have harmful effects.

Example :

Cross I		Cross II	
Inbred A	× Inbred B	Inbred A	× Inbred D
AA bb CC dd	AA bb CC dd	AA bb CC dd	aa BB cc DD
F_1 hybrid		F_1 hybrid	
AA bb CC dd		Aa Bb Cc Dd	
No Heterosis		Heterosis	
(The same no. of genes have dominant alleles as in the two parents. Harmful effects of b and d genes are not masked.)		(Twice as many genes have dominant alleles leading to heterosis because harmful effects of a, b, c & d are hidden by A, B, C & D)	

Fig : Heterosis is the function of the genotypes of the two parents (domiance hypothesis)

[B] Overdominance hypothesis : Overdominance hypothesis is sometimes known as single gene heterosis, superdominance, cumulative action of divergent alleles and stimulation of divergent alleles. The idea of superdominance i.e heterozygote superiority was initially put forth by Fisher in 1903. It was elaborated by East & Shull in 1908 to explain heterosis.

According to overdominance hypothesis, heterozygotes at last some of the loci are superior to both the relevant homozygotes. It means heterozygosity is essential for and is the cause of heterosis while homozygosity resulting from inbreeding produces inbreeding depression.

[C] Epistasis hypothesis : Epistasis is the interaction between two or more non-alleles i.e. different alleles whereas overdominance is the interaction between two alleles.

In 1952, Gowen had suggested that influence of one locus on the expression of another may be involved in heterosis.

In many cases, the effects of a single homozygous recessive allele is epistatic to almost the whole genetic make up of an inbred. When the effects of such an allele are masked by its dominant allele, the effects on heterosis are usually dramatic (Stuber, 1994).

Overdominance is true only in few cases. Similarly epistasis is also less occuring phenomenon. Only common occuring theory is Dominance Theory.

Hybridization

The mating or Crossing of two plants or lines of dissimilar genotype is known as hybridization. In plants, crossing is done by placing pollen grains from one genotype i.e. male parent, on the stigma of flowers of other genotype i.e. female parent. It is essential to prevent self-pollination as well as chance cross-pollination in the flowers of female parent used for crossing.

The seeds as well as progenies resulting from hybridization are called **hybrid or F_1**. The progeny of F_1, obtained from selfing or intermating of F_1 plants, and the subsequent generations are known as **segregating generations.** The term '**Cross**' is often used to denote the products of hybridization i.e. F_1 & segregating generations.

Metaxenia : The effect of pollen on the maternal tissue of the fruit i.e. the pollination effect on the same generation is called Metaxenia.

Sex in plants was discovered by Camararious (1694)

In 1717, Thomas Fairchild produced the first hybrid, the Fairchild's mule, by crossing sweet william with carnation.

Today hybridization is the most common method of crop improvement.

Objective : The main objective of hybridization is to create genetic variation.

The aim of hybridization may be transfer of one or few qualitative characters, improvement of one or more quantitative characters, or use of the F_1 as a hybrid variety.

a) Combination Breeding : The transfer of one or more characters from other varieties into a single variety is known as

combination breeding. Development of disease resistance is the example of combination breeding.

b) Transgressive Breeding : Transgressive segregation means production of plants in F_2 generation which are superior to both the parents for one or more characters. The breeding for improving yield or its contributing characters through transgressive segregation is called Transgressive breeding.

c) Hybrid Varieties : In most self-pollinated crops, F_1 is more vigorous and higher yielding than the parents. F_1 is used directly as a variety.

Types of hybridization : On the basis of taxonomic relationships of the two parents, hybridization is of two types - Intervarietal & Distant hybridization.

1) Intervarietal hybridization : Here parents are of the same species i.e. may be two strains, varieties or races of the same species. This is also known as **intraspecific hybridization-**

Intra - specific means with in species.

Inter - specific means two different species.

Intervarietal means two different varieties

(like inter - cast marriage)

Intervarietal hybridization is the most commonly used in the crop improvement programme. Intervarietal crosses may be simple or complex :-

a) Simple cross : Here two parents are crossed to produce the F_1. F_1 is selfed to produce F_2 or is used in a backcross programme e.g.

$$\begin{array}{ccc} \text{♀} & & \text{♂} \\ A & \times & B \\ & \downarrow & \\ & F_1\ (A \times B) & \end{array}$$

b) Complex cross : Here > 2 parents (more than two parents) are crossed to produce F_1 which is used to produce F_2 or is used in a backcross programme. Such cross is used in converging the genes i.e. bringing the genes from several parents

into a single hybrid. Therefore complex cross is also called **convergent cross.** When F_1 from a simple cross is crossed to a third parent, it is called **three way cross or F_1 top cross.**

When F_1s from two single crossed are mated together, the cross is called **double cross.**

2) Distant hybridization : Here crosses are made between different species of the same genus or of different genera.

Interspecific cross means the cross between two different species of the same genus e.g. *Gossypium arborium* × *Gossypium hirsutum.*

Intergeneric cross means the cross between two different genera. e.g.

Triticum turgidum × *Secale cereale (rye)*

↓

Triticale hexaploide

Generally distant hybridization is made to transfer one or few simply inherited characters like disease resistance to a crop species.

Procedure of Hybridization : There are 7 steps involved in hybridization :- (1) Choice of parents (2) evaluation of parents (3) emasculation (4) bagging (5) tagging (6) pollination (7) harvesting and storage of F_1 seed.

Emasculation : Removal of stamens or anthers or killing the pollen grains of a flower without affecting the female reproductive organs is known as emasculation.

Emasculation = E + masculation

E ↓ removal; masculation ↓ masculine

Emasculation is the removal of masculinity.

Purpose of emasculation : to prevent self - fertilization in the flowers of the female parent. In dioecious plants, male plants are removed. In monoecious plants, male Flowers (in castor) or male inflorescences (in maize) are removed.

Emasculation is essential in bisexual flowers.

Techniques of emasculation :

a) Hand emasculation : Hand emasculation is generally done.

1) in the evening between 4 pm to 6 pm.
2) one day before the anthers are expected to dehisce or mature, and
3) the stigma is like to become fully receptive.

b) Suction method : useful in species with small flowers. Emasculation is done in the morning just before or immediately after opening of the flower. Here suction hose is used to suck the anthers.

c) Hot water Emasculation : In jowar (*S. bicolor*) treatment of flower with water at 42-48^0 C for 10 minutes and in rice *(O. sativa)*, 10 minutes treatment with water at 40-44^{0}C, kill the pollen grains. Hot water treatment is given before anther's dehiscence and prior to opening of flowers.

d) Alcohol treatment : It is not a common method. In Sweet clover, immersion of the inflorescence in 57% alcohol for 10 seconds was highly effective.

e) Cold treatment : In rice cold water treatment at 0-6^0 C kills the pollen grains without affecting gynoecium. Exposure of wheat plant at 0-2^0 C for 15-24 hours kills the pollen grains.

f) Genetic emasculation : Genetic or cytoplasmic male sterility may be used.

Tagging : A tag having the following informations written with a carbon pencil is attached :

i) Date of emasculation.

ii) Date of pollination

iii) Name of the ♀ & ♂ parents. The name of the ♀ parent is written first. e.g. A × B. Here A is ♀ parent and B is the ♂ parent.

Pollination : To bring about fertilization, mature, fertile and viable pollen should be placed on a receptive stigma.

The pollination procedure consists of collecting pollens from freshly dehisced anthers and dusting these pollens on the stigma

of the emasculated flowers.

Production of hybrid seed by hand pollination is commercially feasible in crops like tomato, brinjal & tobacco because each fruit produces a large no. of seeds.

Cornerstones of hybridization

1) Prevention of self pollination in the flowers of ♀ parent is achieved through emasculation of the flowers.
2) Prevention of pollination of the flowers of female parent by pollen from undefined sources is achieved through bagging of flowers.
3) Ensuring pollination by the selected ♂ parent i.e. prevention of contamination of the pollen used for pollination in a crop like maize is achieved through Hand pollination (Bagging of the ♂ inflorescence)

The breeding methods commonly used in cross-pollinated crops-

[A] Population Improvement

Population improvement was the earliest breeding method applied to cross-pollinated crops.

Cross pollinated crops generally show moderate to severe inbreeding depression. Therefore, inbreeding must be avoided or kept to minimum in cross pollinated species.

In cross pollinated species the genotype of the individual plants is generally of little importance particularly in population improvement. Here value of population is determined by the frequency of desirable genes or alleles in the population as a whole.

Population improvement methods are grouped into two general classes.

1) Without progeny testing : Plants are selected on the basis of their phenotype and no progeny testing is carried out e.g. **mass selection.**

2) With progeny testing : Plants are initially selected on the basis of their phenotype but final selection is on progeny testing i.e. **progeny selection** (ear to row method) & **recurrent selection.**

a)Mass Selection : Oldest breeding method for cross pollinated crops. Here a no. of plants are selected on the basis of their phenotypes and open-pollinated seeds from them are bulked together to grow the next generation. No progeny test is conducted.

Mass selection is based on the maternal parent only and there is no control on the pollen (♂) parent.

The same mass selection of self pollinated crops is applied to the cross pollinated crops.

b) Progeny Selection : The Simplest form of progeny selection is ear to row method which has been extensively used in maize. This method was developed by Hopkins in 1908.

Here a no. of plants (50-100) are selected on the basis of their superior phenotypes and are allowed to open pollinate. Seeds from individual plants are harvested separately.

A single row of 10-50 plants i.e. progeny row is grown from each selected plant. The progeny rows are evaluated for desirable characters and superior progenies are identified.

Several phenotypically superior plants are selected and are allowed to open pollinate.

Small progeny rows (10-15 plants) are grown from the selected plants and the process is repeated one or more times and then yield trials are done.

c) Recurrent Selection (RS) : The idea of recurrent selection was first suggested by Hayes and Garber in 1919 and independently by East & Jones in 1920. Hull suggested that recurrent selection may be useful in improving specific combining ability.

In cross-pollinated population, a no. of plants are selected on the basis of phenotype or progeny test and are self-pollinated. The progenies obtained are intercrossed in all possible combinations by hand. Equal amount of seed from each cross is composited to produce next generation.

General combining ability (GCA) : GCA is the average performance of a strain in a series of cross combinations. GCA is estimated from the performance of F_1s from the crosses.

Specific combining Ability (SCA) : SCA is the deviation in perfomance of a cross combination from that predicted on the basis of GCAs of the parents involved in the cross.

Recurrent selection is based on progeny tests and rigid control on pollination. The seeds for progeny tests are obtained :

by **selfing** (i.e. Simple recurrent selection) or by crossing:

to a **tester** with broad genetic base (i.e recurrent selection for **GCA**);

or to an **inbred** (i.e. recurrent selection for SCA).

In **Reciprocal** Recurrent Selection (RRS) two sources of populations are used as testers for each other. Theoretically, in almost all practical situations, Reciprocal Recurrent selection (RRS) may be expected to be superior to recurrent selection for GCA (RSGCA) and Recurrent selection for SCA (RSSCA).

[B] Hybrid & Synthetic Varieties

Hybrid varieties are the first generations (F_1) from crosses between two purelines, inbreds, open - pollinated varieties, clones or other populations that are genetically dissimilar.

Inbred : An inbred is a nearly homozygous line developed by continued inbreeding usually selfing, accompanied by selection.

Sister inbred : The inbreds which have 50% or more genetic commonality.

Single cross : When two inbreds, A & B are crossed to produce the hybrid ($A \times B$), it is called single cross.

Double cross : When two single crosses i.e ($A \times B$) and ($C \times D$) are crossed to produce the hybrid ($A \times B$) × ($C \times D$); it is called double cross. It means double cross involves four inbreds i.e. A, B, C, D which are first crossed to produce two single crosses.

Three-way cross : The Cross between a single cross ($A \times B$) and an inbred (C) to yield the hybrid population ($A \times B$) × C; is known as three-way cross.

Top cross/Inbred-variety cross : When an inbred is crossed with an open-pollinated variety, it is known as top cross or inbred variety cross.

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The cross of selected plants, lines or clones with an open-pollinated variety is also known as **top cross**

The purpose of top cross is to estimate GCA (general combining ability) of the plants or lines crossed with open pollinated variety. When the cross is made to assess combining ability, it is known as **test cross.** The common parent used in test cross is known as **tester** and the progenies obtained from these crosses are called test cross progenies.

Poly cross : Means open-pollination (Assumed to be random mating) in isolation among a number of selected genotypes.

Polycross is the progeny of a line produced through random pollination by a number of selected lines.

Population cross/varietal cross : The cross between two open pollinated varieties is known as population cross or varietal cross.

Types of hybrid	Notation/description
	(I_1 & I_2 etc. are inbreds. I'_1 & I'_2 are sister inbreds of I_1 & I_2 respectively. V_1, V_2 are varieties (Open pollinated).
Single cross	$I_1 \times I_2$
Double cross	$(I_1 \times I_2) \times (I_3 \times I_4)$
Three-way cross	$(I_1 \times I_2) \times I_3$
Modified single cross	$(I_1 \times I_1) \times I_2$
Double modified single cross	$(I_1 \times I'_1) \times (I_2 \times I'_2)$
Modified three way cross	$(I_1 \times I_2) \times I'_3$
Varietal hybrid	$V_1 \times V_2$
Topcross hybrid	$V_1 \times I_1$
Double topcross hybrid	$(I_1 \times I_2) \times V_1$

Hybrid varieties were first commercially exploited in maize. The greatest use of hybrid varieties has been made in maize.

Four hybrids of maize i.e. Ganga 1, Ganga 101, Ranjit & Deccan were released in 1961 in India. All were double crosses.

In India First hybrid variety of **Jowar** *(S. bicolor)* was **CSH_1** (released in 1964) by using cytoplasmic genetic male sterility of **Combine Kafir** 60 as ♀ parent.

In India First hybrid variety of **Bajra** *(P. americanum)* was **HB1** (released in 1965 by using cytoplasmic genetic male sterility of **Tift 23 A** (introduced from tifton, Georgia, USA as ♀ parent). HBI is the single cross.

CSH : Coordinated Sorghum Hybrid

HB : Hybrid Bajra.

In India Hybrid cotton is produced by **hand pollination.**

Hybrid Cotton : India is the first country to exploit hybrid vigour commercially in cotton. All the hybrid varieties have been developed in the tetraploid cottons.

H_4 was the first hybrid variety of cotton developed by Gujarat agriculture university (Surat station) and released in 1970.

Varalaxmi was the First interspecific hybrid variety (cotton) developed by university of agl. Sciences (Dharward station) and released in 1972.

Intraspecific hybrid cotton : by crossing two different strains of *G. hirsutum* i.e. *G. hirsutum* × *G hirsutum. G means Gossypium.*

(1) H_4 (Hybrid - 4), (2) H_6 (3) JKHy 1, (4) Godavari, 5) Suguna' 6) AKH 468 (PKVHy - 2)

Interspecific hybrid cotton : by crossing one strain of *G. hirsutum* with a strain of *G. barbadense.* i.e. *G. hirsutum* × *G. barbadense.*

(1) Varalaxmi (2) Jaylaxmi (3) Savitri, (4) CBS 156 (5) K 2HC.

Hybrid rice in India :

A cytoplasmic Male sterile (CMS) line of rice was first developed in 1972 by Athwal & Birmani by transfering the nuclear genotype of indica rice variety pankhari 203 into the cytoplasm of another indica variety TN-1.

The CMS-WA (wild abortive) cytoplasm was identified in a population of wild rice *(O. sativa f. spontanea)* in the year 1970 in China.

The CMS-WA leads to pollen abortion and is presently used in 95% of the CMS lines used for hybrid rice production.

First hybrid rice APHR-1 was released in 1994. Other hybrid rice varieties:- APHR-2, MGR-1, KRH-1, CNHR-3, DRRH-1.

A basmati hybrid rice named Pusa Rice Hybrid 10 (P RH-10) was developed at IARI, New Delhi.

Commercial hybrid varieties are either single crosses or double crosses. Single cross hybrid varieties are common in bajra, jowar, cotton, rice and in maize (in U.S.A.)

Double cross varieties are common in maize in India.

The largest number of hybrid varieties have been developed in bajra & jowar; (maize stands second).

The predicted performance of any double cross is the average performance of the four non-parental single crosses involving the four parental inbreds e.g. performance of double cross $(A \times B) \times (C \times D)$ would be the average of performance of the single crosses $A \times C$, $A \times D$, $B \times C$ and $B \times D$, since these single crosses are not involved in producing the concerned double cross. This method was developed by Jetkins (1934).

Two requirements of commercial hybrid seed production :

1) Easy emasculation of the ♀ parent.
2) Effective pollen dispersal from ♂ parent to ensure a satisfactory seed set in ♀ parent.

Hybrid seed may be produced by :-

a) Cytoplasmic genetic male sterility
b) Cytoplasmic male sterility
c) Genetic male sterility
d) Self incompatibility
e) Manual emasculation and/or pollination.

Synthetic/Composite Varieties

Synthetic variety is produced by crossing a number of lines that combine well with each other in all combinations. Once synthesized, a synthetic is maintained by open pollination in isolation.

The lines used to produce a synthetic variety are tested for combining ability with each other. Therefore the yield of synthetic varieties can be predicted in advance. GCA is generally estimated by topcross or polycross test.

Composite variety is produced by mixing seeds of several phenotypically outstanding lines and encouraging open-pollination to produce crosses in all combinations among the mixed lines. The lines used to produce a composite variety are rarely tested for combining ability with each other. Therefore the yield of composite varieties can not be predicted in advance.

The first composite varieties in India were released in 1967 : **Six maize composites** = Amber, Jawahar, Kisan, Vikram, Sona & Vijay.

Composite is often used as a synonym for synthetic but is not entirely accurate.

Like synthetics, composites are commercial varieties and are maintained by open-pollination in isolation.

Germplasm Complexes are produced by mixing seed from several lines or populations of diverse genetic origins. The objective of germplasm complexes is to serve as reservoirs of germplasm. Such complexes are experimental populations and not commercial varieties.

The possibility of commercial utilization of synthetic varieties in maize was first suggested by Hayes & Garber in 1912. Synthetic varieties have been of great value in breeding of those cross pollinated crops where pollination control is difficult e.g. **forage crops,** many clonal crops like cacao, alfalfa, clovers etc. The programme at CIMMYT, Mexico & Pearl millet breeding programme at ICRISAT, Hyderabad are based on synthetic varieties.

The performance of synthetic 2 (Syn_2) is expected to be lower than that of Syn_1 due to decrease in heterozygosity due to

random mating. However, there would be no further decline in subsequent generations produced by open-pollination (Syn_3, Syn_4 etc.) because the zygotic equilibrium for any gene is reached after one generation of random mating.

The performance of synthetic varieties is usually lower than the best single or double cross hybrid because synthetics exploit only GCA while hybrid varieties exploit both GCA & SCA (General Combining ability & Specific Combining ability).

Advantages of synthetic varieties :

1) Synthetic varieties are practically feasible means of exploiting heterosis in species where pollination control is difficult.
2) Seed production is simpler & cheaper.
3) Farmer can save his own seed. Synthetics can be maintained for several years from open pollinated seed.
4) Synthetics serve as good reservoirs of genetic variability.
5) Synthetics may be expected to perform better than hybrids in a variable environment because synthetics have wider genetic base in comparison to that of hybrid varieties.

Multiline Varieties :

Multiline varieties are mixtures of several purelines of similar height, flowering & maturity dates, seed colour & agronomic characteristics but they have different genes for disease resistance.

The idea of multiline varieties was put forward by Jenson in 1952 for use in cereals.

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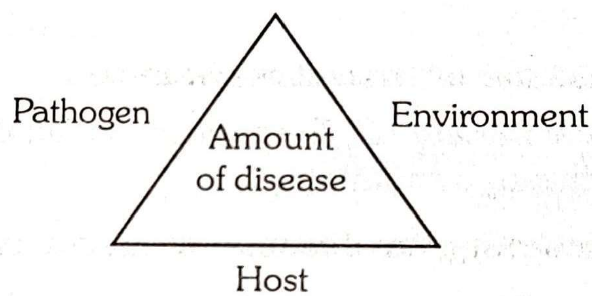
33 Breeding for Disease & Insect Resistance

Disease is an abnormal condition in the plant produced by an organism or an environmental factor. Benedict Prevost in 1807 proved that wheat bunt disease was caused by a fungus.

Pathogenicity is the ability of a pathogen to attack a host and is synonymous to virulence.

Three components viz. Pathogen, Host and Environment are essential for the development of disease. The fourth factor is time.

The interaction between host, pathogen & environment during the development of diseases is represented by a disease-triangle.



Development of diseases caused by fungi occurs in 4 well defined stages :-

(1) Contact means landing of pathogen on the host tissue.

(2) Infection is the process by which the pathogen gains entry into the host tissue.

Both contact and infection stages are greatly affected by environment and provide the means for disease escape.

(3) Establishment : Once the pathogen has entered the host tissue, the pathogen proliferates & spreads within the host tissue. This phase is called establishment. Here disease symptoms are not visible.

(4) Development : Disease symptoms are developed. Here spore production or multiplication is the crucial factor because spores serve as inoculum for uninfected plants.

Disease resistance may be immune reaction (no disease, r =O), resistance (less disease, r > O but < 1) or tolerance (high disease incidence but small loss in yield).

Resistance is also classified as vertical & horizontal. Vertical resistance is oligogenic, pathotype specific and generally shows immunity. Horizontal resistance is polygenic, non- pathotype specific and acts by reducing r, i,e $r > O$ but < 1. The mechanism of disease resistance may be mechanical, due to hypersensitivity, antibiosis or nutritional in nature.

Genetically, resistance may be controlled by

(1) Oligogenes (Oligogenic)	(2) Polygenes (Polygenic)	(3) Plasmagenes i.e. Cytoplasmic

Oligogenes often show **vertifolia effect.** Van der Plank introduced this term derived from the name of a German potato variety Vertifolia with late blight resistance genes R_3 & R_4. This variety became susceptible and complete failure of resistance leading to disease epidemic. Vertifolia effect is the epidemic development in a variety carrying oligogenes leading to heavy economic losses. [See : Varietal control of Integrated Pest Management]

Sources of disease or insect resistance :

(1) a known variety, (2) Germplasm collection, (3) related species & (4) through mutation.

Methods of breeding for disease or Insect resistance :

1) Selection : Cheapest and quickest method for developing a resistant variety.
2) Introduction. means introduction of resistant variety for cultivation in a new area.
3) Mutation : through spontaneous & induced mutaion.
4) Hybridization : most common method of breeding for disease or Insect resistance.

Two main purposes of hybridization :

a) transfer of resistance from an agronomically undesirable variety to a susceptible but otherwise desirable variety (by back cross method). The **backcross method** is useful in oligogenic resistance or vertical resistance.

b) Combining resistance and some other desirable characters of one variety with the superior characteristics of another variety (by pedigree method). **pedigree method** is quite suited for horizontal or polygenic resistance.

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34 Mutations in crop improvement

Mutation is a **sudden heritable change** in the characteristics of an organism.

The term 'mutation' was introduced by **Hugo de Vries** in 1900. His Work was on the evening primrose (***Oenothera lamarchiana***)

A sudden & discontinuous change (i.e. mutation) may be

a) in a single gene (gene **mutation** or point **mutation**) or

b) in the structure of chromosome (i.e. **chromosomal aberration**) or

c) in the number of chromosomes (i.e. polypoidy = **heteroploidy**) or

d) in the plasmagene (i.e. **plasmagene mutation** or **Cytoplasm** mutation) Plasmagenes are the genes present in the chloroplast, mitochondria etc. of the cytoplasm.

MUTATION

- Chromosomal mutation [change in chromosome structure and number]
  - Chromosomal aberration
  - Polyploidy
- Gene mutation or Point mutation [change in gene]

- Visible Mutation [with phenotypic effects]
  - Germinal [in reproductive cell]
    - **Gametic** [sperms or egg]
    - **Zygotic** [zygote]
  - Somatic [in soma; not heritabale]
  - Spontaneous [appears spontaneously in a culture]
  - Induced [induced artificially through mutagenic agents]
  - Reverse [mutated genes again mutates to become normal]
  - Spurious [recessive gene appears phenotypically by crossing over; hidden mutations]
- Biochemical mutation [affects specific biochemical processes]
- Lethal mutation [may cause death of the organism]

Mutation produced by changes in the base sequences of genes are known as gene or point mutation. Base sequences of genes are changed due to base pair transition or transversion, deletion, duplication or inversion etc.

In most of the cases the site of the change is not known. Small changes are rarely detected but they cause mutation.

Somatic/bud mutation is used to denote mutations occuring in buds or somatic tissues, which are used for propagation.

Spontaneous mutations are such mutations which occur in nature without any treatment given by the man but at a low rate. The frequency is 10^{-6} means generally one in ten lacs.

Induced mutations are artificially induced by a treatment with certain physical or chemical agents called **mutagens.**

The change in base sequence of a DNA may occur by

a) Base addition or deletion : Insertion of one or more bases in a DNA molecule is called base addition. The loss of one or more bases is called base deletion.

The addition or deletion alters the code words of genes and ultimately results in the production of an inactive or defective protein which can lead to the death of the cell.

b) Base substitution : Here a nitrogen base of triplet codon of DNA is replaced by another nitrogen base or its some derivatives. It is of two types.

b_1) Transition : Here a purine is replaced by another purine e.g adenine is replaced by guanine or vice-versa; or a pyrimidine is replaced by another pyrimidine e.g. thymine is replaced by cytosine or vice versa. One base substitution affects only one codon thus only one amino acid is altered. The transitional substitution occur due to

i) Tautomerization : The tautomeric shifts occur due to shifts in electrons or protons in the normal nitrogen bases to convert them in their rare states or tautomers. Due to tautomerization, the amino form (NH_2) of cytosine and adenine may convert into imino (-NH) tautomers and keto (C = O) forms of thymine and guanine may convert into

enol (COH) tautomers. The tautomers loss their linkage capacity with their normal partners, thus a tautomer of adenine may link with cytosine instead of linking with its normal partner thymine.

ii) Deamination : The amino group (-NH_2) of a DNA base is replaced by a hydroxyl (-OH) group. Deamination converts cytosine to uracil which pairs with adenine and guanine to xanthine which pairs by two hydrogen bonds with cytosine.

iii) Base analogues : Certain chemical substances having similar molecular structure to the usual DNA bases, are called base analogues. e.g. 5-bromo uracil (5 BUe) in its keto form (BUk) is a structural analogue to thymine (5-methyl uracil)

b_2) Transversion : The substitution or replacement of a purine (adenine or guanine) by pyrimidine (thymine or cytosine) or vice-verse is called transversion. There are eight different types of possible transversions

i.e.	A to T,	A to C,	G to C,	G to T
	T to A,	C to A,	C to G,	T to G

One transversion affects only one codon and hence replaces only one amino acid in the concerned protein.

The transversion mutation is first of all reported by Freese (1959).

Characteristics of Mutation :

1) Mutations are generally recessive but dominant mutations also occur.
2) Mutations are generally harmful to the organism.
3) Mutations are random i.e occur in any gene.
4) Mutations are recurrent i.e same mutation may occur again & again.
5) Induced mutations commonly show pleiotropy, often due to mutations in closely linked genes.

Mutagens : Mutagenic action of X-rays was discovered by **Muller** in 1927 on **Drosophila** and of gamma-rays and X-rays in 1928 by **Stadler** in barley *(H.vulgare)* & maize *(Z. mays)*. Muller was awarded Nobel Prize in 1946 for this.

Immediately after Muller's discovery, the Swedish mutation breeding programme was started in 1929 by Nilsson-Ehle.

Mutagens are the agents used for inducing mutations. Mutagen may be physical or chemical.

[A] Physical mutagens : Different kinds of radiations are called physical mutagens.

A_1) **Ionising radiations** :

i) **Particulate radiations** : e.g. α-rays (densely ionising), β-rays (sparsely ionising), Fast neutrons (densely ionising) & Thermal neutrons (densely ionising)

ii) **Non-particulate radiations** : (electro magnetic radiations) : e.g. X-rays (sparsely ionising) & γ-rays (sparsely ionising)

A_2) **Non-ionising radiations** e.g. ultraviolet (UV) radiations.

[B] Chemical mutagens : Certain chemicals inducing mutations are called chemical mutagens.

B_1) **Alkylating agents** : e.g. Sulphur mustards, Nitrogen mustards, epoxides, imines (e.g. ethylene imine or EI), sulphates & sulphonates (e.g. ethyl methane sulphonate or EMS, methyl methane sulphonate or MMS), diazoalkanes, nitroso compounds e.g. N-methyl-N-nitro-N-nitroso-guanidine or MNNG)

B_2) **Acridine dyes** e.g. acriflavine, proflavine, acridine orange, acridine yellow, ethidium bromide.

B_3) **Base analogues** e.g. 5-bromouracil, 5-chlorouracil

B_4) **Other** e.g. nitrous acid, hydroxyl amine, sodium azide.

Roentgen : Exposure to radiation is measured in Roentgen (R) units. Roentgen is the electric charge produced in dry air under standard conditions by X-rays or γ-rays divided by the mass of air.

$1\ R = 2.58 \times 10^{-4}$ coulomb/kg air

One coulomb is the charge that flows in one second through a conductor that is carrying a current of one ampere. One electron has a charge of 1.6×10^{-19} Coulomb.

LET (Linear Energy Transfer) : is the amount of energy deposited or lost by a particle/photon per unit length of its path.

Sparsely ionising radiations (SIR) : Such radiations which produce a few ionisations per micron of its path having low LET value, are called sparsely ionising radiations e.g. X-rays & γ-rays.

Densely ionising radiations (DIR). Such radiations produce several ionisations per micron having high LET. e.g. α-particles & fast & thermal neutrons.

Alpha-rays : (α-particles) Alpha-particle has 2 protons & 2 neutrons thus having ++ charges and is produced by fission of radioactive isotopes of heavier elements. After losing energy, each α-particle capturing 2 electrons produces an atom of **helium.** α-particle has much less penetrating power than neutrons and β-rays. α-rays move in straight line.

Beta rays (β-rays) : High energy electrons produced by decay of radioactive isotopes e.g. ^{3}H, ^{32}P, ^{35}S etc. β-rays move in a zig-zag line because electrons are easily deflected by atoms in their path. Electrons liberated as a result of ionisation also produce ionization & excitation i.e. they behave like β-rays. β-rays have more penetrating power than α-rays but very little compared to x-rays.

Fast & thermal Neutrons :

Fast neutrons are produced in cyclotrons or atomic reactors as a result of radioactive decay of heavier elements. Its velocity is reduced by graphite or heavy water to generate thermal or slow neutrons. Neutrons are uncharged particles and are highly penetrating in biological tissues. They move in a straight line and do not cause ionisation directly.

X-rays & Gamma (γ) rays : are electromagnetic radiations (high energy) consist of photons. X-rays are produced by X-ray tubes. γ-rays are produced by radioactive decay of certain elements like ^{14}C, ^{60}Co. etc.

^{60}Co is the common source of γ-rays used for biological studies. X-rays having wavelength 0.1-0.001 $\mathring{A}$ are called hard X-rays and having 10-1 $\mathring{A}$ wavelength are called soft x-rays. The electromagnetic radiations produce photo - electric effect, crompton scattering & pair production. Wavelength of x-rays & γ-rays = 0.001-10 $\mathring{A}$. (1 $\mathring{A}$ = 10^{-10}m).

Ultraviolet (UV-rays) :

Wavelength of UV-rays : 100-3900 $\mathring{A}$

UV-rays are present in solar radiation and are produced by mercury vapour lamps or tubes. UV-rays are low energy radiation. UV-rays are known for dimer formation and deamination. The most effective wavelength of UV rays is 2540 $\mathring{A}$ since DNA bases show maximum absorption at this wavelength.

Oxygen effect : Oxygen enhances the biological effects of particularly low LET radiations.

Mutagenesis : Treating of a biological material with a mutagen in order to induce mutations is known as mutagenesis.

Irradiation : Exposure of a biological material to a radiation like X-rays, γ-rays etc. is known as irradiation. The primary effect of radiation is ionisation; the mechanism of ionisation differs to some extent from one radiation to other.

Genetic effects of radiation i.e. effects on DNA means.

a) the change in a base i.e deamination

b) the loss of a base

c) breaking of hydrogen bonds in DNA

d) breaking in single and double strand of DNA

e) cross-linking of DNA strands.

Pyrimidines are more sensitive to radiation damage than purines.

Deamination and intrastrand dimerisation of bases may lead to changed base pairing producing changes in the base sequence of DNA i.e gene mutation.

Mutation breeding : When mutations are induced for crop improvement, the entire operation of the induction and isolation, etc. of mutants is called mutation breeding.

Seeds, pollen grains or vegetative propagules (buds & cuttings) may be used for mutagenesis. In sexually propagated crops, seeds are the most commonly used plant part. In case of clonal crops buds or cuttings are used for mutagenesis. Chemical mutagens are best used with seeds.

Whole plants are generally irradiated during the **flowering stage** so that it is equivalent to irradiation of pollen grains and egg cells. Treatment of whole plants requires special facilities i.e a gamma garden.

Gamma garden : It is an area subjected to gamma-irradiation. This area is enclosed by thick high walls. The purpose of γ -garden is to irradiate whole plants during different stages of development and for varying durations. The source is in centre.

First γ -garden was built in **Long island** near **New york (USA)**. The ist γ -garden in **India** was installed in **calcutta** (Kolkatta) at Bose Research Institute in 1959. In 1960. 2nd γ -garden was built at IARI, New Delhi. 3rd γ -garden was built at Bhabha Atomic Research centre, Trombay. The source of γ -garden was 6g of ^{60}Co in form of small pellets. The strength of ^{60}Co source was 200 curies.

The γ -garden at IARI & BARC and at most other places in the world have now been dismantled because of their high cost.

Optimum dose of mutagen : An optimum dose is the one which produces the maximum frequency of mutations and causes the minimum killing. A dose close of LD^{50} is the optimum.

LD_{50} is the dose of mutagen which would kill 50% of the treated individuals.

Treatment of seeds and vegetative propagules commonly produces chimeras.

A **chimera** is an individual with one genotype in some of its parts and another genotype in the others.

The Ist variety developed from mutagenesis programme was **Primax white Mustard** *(Brassica hirta)* released in 1950.

Jaganath rice is a gamma-ray induced semidwarf mutant from the tall cultivar T 141.

Sonora- 64 was irradiated by M.S. Swaminathan and named them Sarbati-Sonora.

Prabhavati variety of rice is an induced mutant from the tall, scented variety Ambemohar Local, which was treated with 0.2% EMS.

Sugarcane variety Co 8152 is a gamma-ray induced mutant from Co 527.

Mutant cotton varieties MCU 7 & 10 were developed through induced mutations.

In terms of Field crops in India, rice has maximum mutant varieties (24) followed by barley (12 varieties), cotton (8 varieties), groundnut (8 varieties) etc.

China has developed the largest number of mutant varieties followed by India, Russia & Japan.

*

35 Polypoidy

Heteroploid = Hetero + ploid

$\downarrow$ different $\quad$ $\downarrow$ multiple

Individual carrying chromosome numbers other than the diploid (2x & not 2n) number are known as heteroploids and such situation is known as heteroploidy.

x = basic chromosome no. or genomic number

n = Somatic chromosome no. of the species whether diploid or polypoid.

In a diploid species, n = x.

The change in chromosome number may be either in an exact multiple of the basic number (i.e. Euploidy) or in not an exact multiple of the basic number.

Change in chromosome no.
(heteroploidy)

- Euploidy (exact multiple of one genome set)
  - Autopolyploid
    - Autotriploid
    - Autotetraploid
    - Auto pentaploid
    - Auto hexaploid
    - Auto octaploid
  - Allopolypoid
    - Allotetraploid
    - Allohexaploid
    - Allooctaploid
- Aneuploidy (one or few chromosomes extra or missing
  - Hypoploidy
    - Monosomy (2n-1)
    - Nullisomy (2n-2)
    - Double mono somy (2n-1-1)
  - Hyper ploidy
    - Trisomy (2n+1)
    - Tetrasomy (2n+2)
    - Double trisomy (2n+1+1)

Table : A summary of terms used to describe heteroploidy (variation in chromosome number)

Term	*Type of change*	*Symbol*
Heteroploid	change from 2x	
A. Aneuploid	One or a few chromosomes extra or missing from 2n	$2n \pm few$
Nullisomic	One chromosome pair missing	**2n-2**
Monosomic	One chromosome missing	**2n-1**
Double monosomic	One chromosome from each of two different chromosome pairs missing	2n-1-1
Trisomic	One chromosome extra	**2n+1**
Double trisomic	One chromosome from each of two different chromosome pairs extra	2n+1+1
Tetrasomic	One chromosome pair extra	**2n+2**
B. Euploid	Number of genomes more than two	
1. Autopolyploid	Genomes identical with each other	
Monoploid	One genome	x
Autotriploid	Three genomes	3x
Autotetraploid	Four genomes	4x
Autopentaploid	Five genomes	5x
Autohexaploid	Six genomes	6x
Autooctaploid	Eight genomes	8x
2. Allopolyploid	Two or more distinct genomes (generally each genome has two copies)	
Allotetraploid	Two distinct genomes	$(2x_1+2x_2)$**
Allohexaploid	Three distinct genomes	$(2x_1+2x_2+2x_3)$**
Allooctaploid	Four distinct genomes	$(2x_1+2x_2+2x_3+2x_4)$**

* It is, in fact, not a polyploid situation.

n = Somatic chromosome number of the species, whether diploid or polyploid.

x = The basic chromosome number or genomic number.

x_1, x_2, x_3, x_4 = Distnct genomes from different species.

** In general, this condition occurs; other situations may also occur.

Euploidy : Eu + Ploidy

↑ ↑

good multiple

Individuals having exact multiple of the basic or genomic number are known as euploids and the situation is known as euploidy. Euploidy is more commonly known as **polyploidy**. **Polypoid** is an individual having more than two basic or monoploid sets of chromosomes and the condition is known as polypoidy.

When all the genomes present in a polyploid species are identical i.e chromosomes derived from parents with similar genomes, it is known as **autopolyploid.** The genetic composition of autotetraploid may be given as AAAA. Autopolyploid plants are generally larger than their diploids but their fertility is somewhat reduced. Cytologically autopolyploid is identified by the presence of multivalents formed at metaphase of meiosis I.

Whereas individuals having two or more distinct genomes are called **allopolypoids** means polypoids arising from hybridization of two species or genera with subsequent duplication of each chromosome complement are allopolypoids. Here chromosomes are derived from parents with different genomes. The genetic composition of allotetraploids may be AABB.

The doubling of chromosome number in a hybrid is the basis of allopolyploid.

Pairing between two or more homologous chromosomes (e.g. **Raphanobrassica**- cross between *Raphanus sativus* and *Brassica oleracea*) is called **autosyndesis.**

Pairing between two or more non-homologous chromosomes whether it be complete or partial is called **allosyndesis.**

Amphidiploid is an allopolypoid that has two copies of each genome and consequently behaves as a diploid during meiosis. A **segmental** allopolypoid contains 2 or more genomes which are identical with each other except for some minor differences.

Aneuploidy :

An aneuploid has a chromosome no. that is not an exact multiple of the basis chromosome number (x). In other words the addition or deletion of one or more chromosomes or pairs of chromosomes but not the whole complement is known as aneuploidy.

The aneuploidy is the resultant of nondisjunction of the chromosomes during cell division.

The Ist variation in chromosome number (heteroploidy) discovered in an experimental population was **gigas mutant** in **Oenothera** described by **Lutz** in 1907. The gigas was an autotetraploid (4n). In 1910 Blakeslee discovered the globe mutant of *Datura stramonium* (dhatura) which was subsequently demostrated by Belling (1920) to be a trisomic and this was the **Ist** reported case of **aneuploidy.**

Ist **autotetraploid** was experimentally induced by **Winkler** in 1916 in *Solanum nigrum.*

Ist synthesized species : Triticale by **Rimpau** (but with no full information like chromosome no.) in 1890 from a cross between **Triticum & Secale.**

1st synthesized species with full information:-

Nicotiana digluta obtained by spontaneous chromosome doubling of F_1 hybrid from interspecific cross between

Nicotiana glutinosa × *Nicotiana tabacum*

(n = 12,) ♀ (n = 24, ♂)

↓

F_1

↓ Chromosome doubling

N. digluta

synthesized by **Claussen** & **Goodspeed** (1925)

The chromosome doubling action of **colchicine** was Ist described by Blakeslee and Nebel in 1937 but the effect of colchicine on mitosis was discovered in 1955.

Colchicine is a poisonous chemical isolated from seeds (0.2-0.8%) and bulbs (0.1-0.5%) of autumn **crocus** *(Colchicum*

autumnale). Pure colchicine is $C_{22}O_6$ N. It blocks spindle formation and thus inhibits movement of sister chromatids to the opposite poles.

A trisomic (2n+1) is known as **primary trisomic** when the extra chromosome is the same as one of the haploid genome means it is not modified. But when additional chromosome is an iso- chromosome (two arms of the chromosome are identical), it is called **secondary trisomic** and when the extra chromosome is translocated chromosome, it is called **tertiary trisomic.**

The best source of aneuploids are triploid plants. Meiotic irregularities lead to formation of n+1 and n-1 gametes.

Aneuploids are generally weaker than diploids. Monosomics don't survive in diploid species. Only trisomics survive in diploid species.

Aneuploids are useful in locating a linkage group and a gene to a particular chromosome.

Aneuploids are useful in production of substitution lines.

Chromosome substitution means the transfer of a pair of chromosomes from one strain into a different strain. Chromosome substitution is easily done using nullisomics of the variety into which the chromosome is to be transferred (recurrent parent) but monosomics are used more commonly in place of nullisomics.

Features of autopolypoids :

Polypoids have larger cell size than diploids, larger guard cells of stomata, larger pollen grains, slower in growth and later in flowering, larger and thicker leaves, larger flowers & fruits but lesser in number than of diploids, reduced fertility due to meiotic irregularity and genotypic imbalances.

Autotriploids are generally highly sterile e.g. water melons, banana etc. but in some cases they are highly fertile e.g spinach.

In autotetraploid, 4 chromosomes are homologous to each other, hence each gene has 4 copies.

Individual	dominant alleles	recessive alleles	genotype
Simplex	1	3	Aaaa
Duplex	2	2	AAaa
Triplex	3	1	AAAa
Quadruple	4	0	AAAA
Nulliplex	0	4	aaaa

Autopolypoid played a limited role in the evolution of plant species. Autopolypoid crops are potato (4x), alfalfa (4x), banana (3x), sweet potato (6x).

Common name	**Scientific name**	**Somatic chromosome number (2n)**	**Remarks**
Potato	*Solanum tuberosum*	48 (4x)	Autopolypoid
Alfalfa	*Medicago sativa*	32 (4x)	"
Banana	*Musa sapientum* (*M. paradisiaca*)	33 (3x)	"
Sweet Potato	*Ipomoea batatas*	90 (6x)	"
Groundnut (Peanut)	*Arachis hypogea*	40 (4x)	Previously autopolypoid but presently
Coffee	*Coffea arabica*	44 (4x)	considered as allopolypoids.

Triploids : Produced by hybridization between tetraploid and diploid strains; generally highly sterile, useful in production of seedless watermelons. **Seedless watermelons** are produced by crossing tetraploid (4x, ♀) and diploid (2x, ♂) lines and are grown commercially in Japan. They do not produce true seeds.

Triploid sugarbeets have larger roots and produce more sugar per unit area than diploids. Triploid sugarbeets were grown commercially in Europe and Japan but their popularity is declining. Seed production is difficult because beet flower is small.

A triploid (3x) clone of tea (*Camelia assamica*) has been released for commercial cultivation in northern India. Triploid cultivar TV 29 produces larger shoots & biomass; yields

more cured leaf per unit area and tolerant to drought than available diploid varieties.

Triploids can't be maintained except through clonal propagation.

Tetraploids : Some autotetraploids may be superior in some quality characters to their respective diploids e.g. tetraploid maize has 43% more carotenoid pigment and vitamin A.

Certain distant crosses are not successful at the diploid level, but are relatively successful at the autotetraploid level e.g. 4x *Brassica oleracea* × *B. chinensis* is successful.

Autotetraploid varieties of forage crops are proved successful e.g. tetraploid red clover *(Trifolium pratense)*, rye grass *(Lolium perenne)*, aliska clover *(Trifolium hybridum variety Tetra)* and Berseem *(Trifolium alexandrium)* variety Pusa Giant have been proved most successful. Autotetraploid red clover and ryegrass are more vigorous, more digestible and palatable and have greater resistance to nematodes as compared to dipoids.

Autotetraploid turnips *(B. rapa)* and cabbage *(B. oleracea)* are larger in size and have more water content than diploids. Many ornamental plants are autotetraploids which have increased flower size and longer flowering duration.

Pusa Giant Berseem is the Ist autopolypoid variety released for general cultivation in India. It yields 20-30% more green fodder than diploid varieties. **Sugandha** is an autotetraploid variety of vetiver *(Vetiveria zizanoides)* which gives 11% more oil yield. Variety HMT-1 of *Hyoscyamus niger* is an autotetraploid which gives 15% more biomass and 36% more crude drug yield than diploid parent.

Allopolypoids : The present day allopolypoids were most likely produced by chromosome doubling in F_1 hybrids between two distinct species belonging to the same genera or to different genera.

Homoeologous chromosome (Partially homologous chromosome). The partially similar chromosomes but not exact identical, are called homoeologous chromosome. Chromosomes of related species are partially similar to each other and are called homoeologous chromosomes. It means interspecific hybrids have two or more homoeologous chromosomes.

Amphidiploid : An allopolypoid having two copies of each of the two or more different genomes present. Thus an amphidiploid has the somatic chromosome complement of two or more diploid series.

Diploidization : The process due to which allopolypoids show diploid like behaviour i.e only bivalent formation, is known as diploidization.

Synthesis of Triticale & Raphanobrassica :

Parental species	*Triticum turgidum*	*Secale cereale*	Two distinct species are hybridized
Genomes	*AA BB*	*RR*	
Gametes	AB	R	

ABR — The F_1 hybrid is highly sterile; chromosome number of the hybrid is doubled by using colchicine

Colchicine (Chromosome doubling)

Amphidiploid	AA BB RR *Triticale hexaploide* (Allohexaploid)	Fertile allopolyploid (amphidiploid) species distinct from the two parental species.

Fig. Experimental production (synthesis) of an allopolyploid. The allopolyploid synthesised here is an allohexaploid, the hexapolyploid triticale (*Triticale haxaploide*).

Hardiness of rye *(Secale cereale)* and yielding ability of wheat *(Triticum turgidum)* were combined in *Triticale hexaploide.* But in **Raphanobrassica,** the aim was not fulfilled. The aim in producing **Raphanobrassica** was to synthesize a crop species that would combine the root of radish (*R. sativus*) with the leaves of cabbage

(*B. oleracea*). **Raphanobrassica** combined the leaves of radish and roots of cabbage.

Triticale varieties are mainly grown in Polland, Germany & France.

Many of allopolypoids are apomictic. Apomictic species are common in grasses e.g **Poa**., Taraxacum, Parthenium, Rubus etc.

Allopolypoids have been more successful as crop species than autopolypoids. About $^1/_3$rd of the angiosperms are polypoids and by far the vast majority of them are allopolypoids.

The synthetic allopolypoid does often resemble in many ways with natural allopolypoids.

Evolution of Bread wheat (*Triticum aestivum*) Bread wheat appeared about 8000 years ago as a hybrid between *T. turgidum* (♀) and *T. tauschii* (♂) possible in the regions of northern Iran and Armenia, where natural hybrids between *T. turgidum* & *T. tauschii* can be found in farmer's field.

♂ *Triticum monococcum* var. *urartu* (n = 7, AA) × ♀Unknown (n = 7, BB)

↓

AB F_1 sterile

↓ Spontaneous Chromosome Doubling

♂*T. tauschii* (n = 7, DD) × ♀AA BB (n = 14) Amphidiploid — Tetraploid emmer wheats (*T. turgidum var. dicoccoides*)

↓

ABD F_1 sterile

↓ Spontaneous Chromosome Doubling

AA BB DD (n = 21) Amphidiploid — Hexaploid wheats

Fig. Currently accepted evolutionary history of hexaploid wheat.

Previously considered that the source of 'B' genome was *Aegilops speltoides* and 'D' genome was *Aegilops squarrosa*.

Evolution of Amphidiploid Brassica Species :

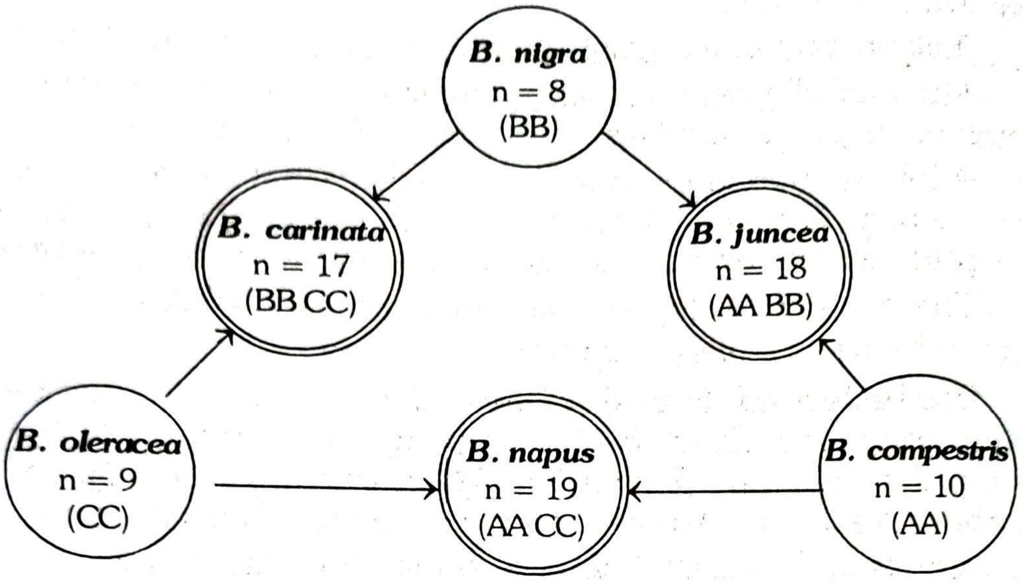


Fig. U's triangle showing the relationships between diploid and naturally occurring amphidiploid species of Brassica. The three diploid species are represented at the three tips of the triangle; their amphidiploids are presented midway between the parental species (and are encircled by two concentric circles).

* Letters within parentheses denote the genomic symbols.

The origin of amphidiploid Brassica species is based on the famous U's triangle proposed by N.U. in 1935.

Evolution of *Nicotiana tabacum* :

Nicotiana sylvestris × *N. tomentosa*

n = 12   n = 12

↓

Nicotiana tabacum

(n = 24)

amphidiploid

Evolution of *Gossypium hirsutum* :

G. herbaceum × *G. raimondii*

Var. *africanum*

↓

F_1

↓ doubling of chromosome

G. hirsutum

Fig. recent view of evolution of *G. hirsutum*

$$
\begin{array}{ccc}
\textit{G. arboreum} & \times & \textit{G. thurberi} \\
\text{(Asiatic cotton)} & \big\downarrow & \text{(American wild cotton)} \\
 & F_1 & \\
 & \big\downarrow \text{ Chromosome doubling} & \\
 & \textit{G. hirsutum} &
\end{array}
$$

Fig. : Previous view of evolution of *G. hirsutum.*

❋

36 Objective Model Question

1. Match List-I (Crop species) with List-II (Serious disease) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Rice	1. Green ear
B. Wheat	2. Bacterial leaf blight
C. Maize	3. Stalk rot
D. Bajra	4. Alternaria leaf blight

CODES

(a)	A	B	C	D
	1	2	3	4
(b)	A	B	C	D
	2	3	1	4
(c)	A	B	C	D
	2	4	3	1
(d)	A	B	C	D
	4	3	2	1

2. Which of the following pairs of wheat rusts and alternate hosts are correctly matched?
(1) Puccinia graminis tritici..........Berberis vulagaris
(2) Puccinia recondita tritici.........Thalictrum spp.
(3) Puccinia striiformis.............Phalaris minor.
Select the correct answer using the codes given below:
CODES :
(a) 1, 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 2 and 3

03. Match List-I (Crop disease) with List-II (Pathogen) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Tikka disease of groundnut	1. Erysiphe graminis f.s.p. hordei

B. Powdery mildew of barley — 2. Puccinia striiformis
C. Yellow rust of wheat — 3. Plasmopara viticola
D. Downy mildew of grapes — 4. Cercospora personata

CODES :

(a)	A	B	C	D
	2	1	4	3
(b)	A	B	C	D
	2	3	1	4
(c)	A	B	C	D
	4	1	2	3
(d)	A	B	C	D
	4	3	2	1

4. Which one of the follwing pairs of crop and disease is correctly matched?
   (a) Cabbage — Early blight
   (b) Cucumber — Club root
   (c) Potato — Black ward
   (d) Tomato — White rust
5. Which one of the follwing pairs is NOT correctly matched?
   (a) Karnal bunt of wheat — Neovossia horrida
   (b) False smut of rice — Ustilaginoidea virens
   (c) Hill bunt of wheat — Tilletia foetida
   (d) Ear cockle of wheat — Anguina tritici
6. Plant pathogenic viroids contain
   (a) RNA only
   (b) RNA and protein coat
   (c) DNA and protein coat
   (d) DNA only
7. Loose smut of wheat is a/an
   (a) externally seed-borne disease
   (b) externally seed-borne and soil-borne disease
   (c) air-borne disease
   (d) internally seed-borne disease
8. Which of the following are the sources of survival of the wilt pathogen of sugarcane in India?
   (1) Ratoon of infected crop
   (2) Diseased plant debris
   (3) Setts of diseased crop
   (4) Collateral hosts

Select the correct answer using the codes given below:
CODES:
(a) 1, 2, 3 and 4
(b) 2 and 3
(c) 3 and 4
(d) 1, 2 and 3

9. Which one of the following is the correct order in which they appear during biocontrol operations?
(a) Parasite, Release, Mass rearing, Parasitism
(b) Mass rearing, Parasite, Release, Parasitism
(c) Release, Mass rearing, Parasite, Parasitism
(d) Parasite, Mass rearing, Release, Parasitism

10. The following major events occur during the pathogenesis of a host by a pathogen:
(1) Landing of inoculum
(2) Recognition
(3) Germination of the propagules
(4) Penetration
(5) Establishment
(6) Development of symptom
The correct sequence of these events in disease development is
(a) 1, 2, 3, 4, 5, 6
(b) 1, 3, 4, 2, 5, 6
(c) 1, 2, 4, 3, 5, 6
(d) 1, 3, 2, 4, 5, 6

11. Mycoplasma is sensitive to
(a) penicillin
(b) tetracyclin
(c) calixin
(d) streptomycin

12. Whorl application of granular insecticide provides effective control measure against:
(a) spotted bollworm
(b) maize stem borer
(c) stem borer of paddy
(d) mango stem borer

13. Match List-I (Principles of disease control) with List-II (Practices) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Exclusion	1. Spraying a common fungicide
B. Avoidance	2. Chemical seed treatment
C. Eradication	3. Isolation in time and space
D. Protection	4. Plant quarantine

CODES :

	A	B	C	D
(a)	3	4	2	1
(b)	3	4	1	2
(c)	4	3	1	2
(d)	4	3	2	1

14. Which one of the following insecticides is capable of controlling mites as well?
(a) Endosulfan
(b) Toxaphene
(c) Cypermethrin
(d) Monocrotophos

15. The safest method of disposing off the left over pesticide is, disposal by :
(a) pouring in the drain
(b) pouring in a pond
(c) pouring in a moving stream
(d) burying in the soil

16. Which of the following types of manually operated sprayers are suitable for spraying 4 to 5 metre tall plantations?
(1) Hand compression sprayer
(2) Knapsack sprayer
(3) Foot sprayer
(4) Rocking sprayer

Select the correct answer using the codes given below:
CODES :
(a) 1, 2, 3 and 4 (b) 2 and 4
(c) 1, 2 and 3 (d) 3 and 4

17. Which of the following protective measures are necessary for a person manually dusting pesticide on crop in uncertain wind conditions?
    (1) Wearing plastic aprons
    (2) Use of plastic gloves
    (3) Use of plastic shoes
    (4) Use of goggles
    (5) Use of nose filters

    Select the correct answer using the codes given below:
    CODES :
    (a) 1, 2, 3, 4 and 5
    (b) 1, 2, 4 and 5
    (c) 2, 3 and 4
    (d) 1, 3 and 5
18. If one gram of a pesticide formulation containing 50% active ingredient is mixed with one litre of water, what will be the concentration of the active ingredient in the spray fluid?
    (a) 0.5 ppm
    (b) 5.0 ppm
    (c) 50 ppm
    (d) 500 ppm
19. Assertion (A) : Philosophy of pest control based on eradi cation of pest spices is the antithesis of in tegrated pest control.

    Reason (R) : Eradication of pest spices leads to an unstable biotic community.
20. Assertion (A) : The broad spectrum insecticide needs to be used for all agricultural crops.

    Reason (R) : Broad spectrum insecticide kills a large variety of insects.
21. Consider the following statements regarding enzymes in living plants:
    (1) They are specific.
    (2) They are sensitive to heat.
    (3) The reactions caused by enzymes are reversible.
    (4) They exist in a colloidal state.

Of these statements
(a) 1 and 2 are correct
(b) 1, 3 and 4 are correct
(c) 2, 3 and 4 are correct
(d) 1, 2, 3 and 4 are correct

22. Which one of the following plant nutrients is useful in increasing resistance to diseases and insect pests?
(a) Calcium
(b) Phosphorus
(c) Nitrogen
(d) Potassium

23. Parts of cell walls in plants are given in List-I and their distinctive components are given in List-II. Match the two lists and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Primary wall	1. Hemicellulose
B. Secondary wall	2. Lignin
C. Middle lamella	3. Lipids and proteins
D. Plasma lemma	4. Pectin

CODES :

(a)	A	B	C	D
	1	2	3	4
(b)	A	B	C	D
	2	1	4	3
(c)	A	B	C	D
	2	1	3	4
(d)	A	B	C	D
	1	2	4	3

24. During the conversion of each molecule of glucose into pyruvic acid through the glycolytic cycle
(a) one Molecule of ATP is consumed and two molecules of ATP are generated
(b) two molecules of ATP are consumed and two molecules of ATP are generated
(c) one molecules of ATP is consumed and four molecules of ATP are generated
(d) two molecules of ATP are consumed and four molecules of ATP are generated

25. Which is the correct chronological sequence of the following discoveries related to mechanism of photosynthesis?
(1) Calvin's cycle
(2) Hatch and Slack cycle
(3) Hill reaction
(4) Red drop
Choose the correct answer using the codes given below:
(a) 3, 4, 2, 1
(b) 4, 3, 2, 1
(c) 3, 4, 1, 2
(d) 4, 3, 1, 2

26. Match List-I (Plant growth regulators) with List-II (Possible precursors) and select the correct answer using the codes given below the lists:

List-I	List-II
A. ABA	1. Tryptophan
B. Ethylene	2. Terpenoids
C. GA_3	3. Fatty acids
D. IAA	4. Carotenoids

CODES :

	A	B	C	D
(a)	4	2	3	1
(b)	2	3	1	4
(c)	4	3	2	1
(d)	3	2	1	4

27. Which of the following chemicals are responsible for the induction of female flower?
(1) Ethephone
(2) GA_3
(3) NAA
(4) Morphactine
Select the correct answer using the codes given below:
CODES:
(a) 1 and 4 (b) 2 and 4
(c) 1 and 3 (d) 3 and 4

28. The main function of maleic hydrazide is considered to be that of a/an
(a) antiauxin
(b) antagonist to gibberellin
(c) inhibitor
(d) growth retardant

29. Khaira disease of rice can be controlled by spraying
(a) copper sulphate
(b) manganese sulphate
(c) borax
(d) zinc sulphate

30. Which of the following are features of CO_2 metabolism of succulent plants with CAM?
(1) Nocturnal stomatal opening
(2) Night-time transpiration
(3) Night-time CO_2 uptake
(4) Decrease in acidity during the night
Select the correct answer using the codes given below:
CODES:
(a) 2, 3 and 4 (b) 1, 2 and 4
(c) 1, 3 and 4 (d) 1, 2 and 3

31. There is a definite relationship between the extent of accumulation of a particular metal ion and the extent of stomatal opening. The metal ion in question is
(a) calcium
(b) magnesium
(c) potassium
(d) sodium

32. The photosynthetic pigment which ocurs in red and blue green algae is
(a) chlorophyll (b) carotenoid
(c) cytochrome (d) phycobilin

33. Evidence for universal nature of flowering hormone has emerged from experiments involving
(a) defoliation
(b) reciprocal grafting
(c) night interruption
(d) application of hormones

34. Substitude adenine compounds which promote cell division in plant tissues would include
(a) cytokinins
(b) gibberellins
(c) morphactins
(d) triacontanols

35. When meristems of plants become dormant, there is
(a) inhibition of auxins
(b) inhibition of cytokinins
(c) inhibition of gibberellins
(d) accumulation of abscissic acid

36. Which of the following pairs are correct matched?

1.	Internal necrosis of jack fruit	Boron deficiency
2.	'Black tip' of mango	Air pollution (fumes from brick kilns
3.	'Cavity spot' of carrot	calcium deficiency

Select the correct answer using the codes given below:
CODES :
(a) 1, 2 and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3

37. Coffee rust is caused by
(a) Uromyces hobsoni
(b) Hemileia vastatrix
(c) Cronartium ribicola
(d) Ravenelia emblicae

38. The plant disease primarily responsible for the "Great Bengal Famine" of 1943 was
(a) blast disease of rice
(b) bacterial blight of rice
(c) udbatta disease of rice
(d) brown leaf spot of rice

39. Pectinolytic enzymes of plant pathogens play a major role during pathogenesis in diseases like
(a) rusts
(b) downy mildew
(c) wilts, damping-off and root/footrots
(d) powdery mildew

40. Which one of the following insects is a gregarious pest?
(a) Sorghum shoot fly
(b) Spotted bollworm

(Crops)	(Smut diseases)
A. Barley	1. Grain smut
B. Paddy	2. Whip smut
C. Sorghum	3. False smut
D. Sugarcane	4. Flag smut
	5. Covered smut
	6. Stinking smut

Codes :

	A	B	C	D
(a)	5	3	2	6
(b)	5	3	1	2
(c)	1	4	2	6
(d)	1	5	4	6

42. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I (Disease)	**List-II** (Casual organism)
A. Wart disease of potato	1. Phytophthora parasitica
B. White rust of crucifers	2. Albugo candida
C. Blister blight of tea	3. Uncinula necator
D. Panama disease of banana	4. Synchytrium endobioticum
	5. Exobasidium vexans
	6. Fusarium oxysporum f.s.p. cubense

Codes :

	A	B	C	D
(a)	2	4	3	1
(b)	4	2	5	6
(c)	1	2	3	6
(d)	2	4	5	3

43. Which one of the following is the correct mode of infection in Ergot of bajra (pearl millet)?
    (a) Shoot infection
    (b) Local infection of blossom
    (c) Seedling infection
    (d) Systemic infection
44. Which one of the following is truly diagnoses the infestation by the shorghum shootfly?
    (a) Formation of 'dead heart' in the early seedling stage of sor ghum which can be easily pulled out
    (b) Formation of 'dead heart' and a bunchy top during the later seedling stage of sorghum
    (c) Formation of 'dead heart' which can not be easily pulled out during the later seedling stage of sorghum
    (d) Formation of silvery shoot during the early seedling stage of sorghum.
45. Tomato leaf curl virus is transmitted by
    (a) aphid (b) whitefly
    (c) grasshopper (d) butterfly
46. Which one of the following pests is controlled through the application of a grease band around the tree trunk?
    (a) Mango mealy bug
    (b) Trunk borer of mango
    (c) Codling moth on apple
    (d) Woolly aphis on apple
47. Identify the correct sequence in which fungitoxic activity of the following were reported:
    1. Dithocarbamates 2. Bordeaux mixture
    3. Captan 4. Oxathin derivatives

Codes :
(a) 1, 2, 3, 4
(b) 2, 1, 4, 3
(c) 2, 1, 3, 4
(d) 1, 2, 3, 4

48. The quantity of endosulphan 35% EC required for treating an area which needs 1000 litres of spray fluid at 0.05% (a.i.) strength is
(a) 35 x 0.05 / 1000 litres
(b) 2.5 x 1000 / 1000 litres
(c) 1000 x 0.05 / 35 litres
(d) 35 x 1000 / 0.05 litres

49. Which one of the following tissues is most suitable for tissue culture to produce virus-free plants of potato?
(a) Leaf tissue
(b) Pollen
(c) Embryo tissue
(d) Meristem tip tissue

50. The size (in micrometers in diameter) of droplets produced by high volume sprayers should most appropriately be
(a) 200 to 500
(b) 100 to 150
(c) 81 to 100
(d) 30 to 40

51. Consider the following statements :
The rate of application of spray fluid per unit area is regulated by the
(1) operating pressure
(2) size of nozzle apperture
(3) swath width
(4) speed of the operator
Of these statements
(a) 1, 2 and 3 are correct
(b) 3 and 4 are correct
(c) 1, 2 and 4 are correct
(d) 1, 2, 3 and 4 are correct

52. Spraying of one hectare of cotton crop is done using 500 litres of spray fluid prepared from 2 kg. of carbaryl 50% water dispersible powder. The concentration of active ingredient of carbaryl in the spray fluid is
(a) 1%
(b) 0.2%
(c) 0.1%
(d) 0.5%

53. Assertaion (A) : Low volume (LV) sprays are more eco nomic than high volume (HV) sprays.
Reason (R) : Less quantity of pesticide is required per unit area for LV sprays when compared to the HV sprays.

54. Assertion (A) : Integrated pest management is a part of sustained agriculture.
Reason (R) : Integrated pest management protects the crop against harmful pests with minimum pollution hazard to the environment and leads to increased food production.

55. Assertion (A) : Epyphytotic of late blight of potato in 1845 forced man to realise the importance of plant diseases.
Reason (R) : In 1845 there was famine in Ireland and many people died of hunger and disease.

56. Match List-I (Symptomps) with List-II (Causes) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Khaira disease of rice	1. Phophorus deficiency
B. Browning of cauliflower	2. Molybdenum deficiency
C. Purple colouration of maize leaves	3. Potassium deficiency
D. Firing of tobaco leaves	4. Zinc deficiency

Codes :

	A	B	C	D
(a)	2	4	3	1
(b)	2	4	1	3

(c)	A	B	C	D
	4	2	3	1
(d)	A	B	C	D
	4	2	1	3

57. The uptake of oxygen and production of carbon dioxide in light by photosynthesising tissue is called
(a) respiration
(b) photo respiration
(c) ground respiration
(d) salt respiration

58. The link between glycolysis and citric acid cycle is the oxidative decarboxylation reaction to form
(a) pyruvate
(b) acetyl CoA
(c) oxaloacetate
(d) citrate

59. Indole acetic acid belongs to which one of the following groups of plant growth hormones?
(a) Gibberellins (b) Auxins
(c) Kinins (d) Vitamins

60. In plants, growth rate, protein synthesis and potassium uptake are stimulated by
(a) cytokinins (b) enzymes
(c) auxin (d) ethylene

61. The growth hormone which overcomes genetic dwarfism in certain plants and causes elongation of intact plant is
(a) gibberellin
(b) auxin
(c) abscisic
(d) cytokinin

62. Match List-I (Diseases) with List-II (Casual organisms) and select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Citrus canker	1. Pseudomonas solanacearum
B. Black rot	2. Agrobacterium tumefaciens
C. Brown rot	3. Xanthomonas compestris pv.
D. Crown gall	4. Xanthomonas compestris pv. citri

CODES :

(a)	A	B	C	D
	4	3	1	2
(b)	A	B	C	D
	3	4	2	1
(c)	A	B	C	D
	3	4	1	2
(d)	A	B	C	D
	4	3	2	1

63. Which of the following pairs are correctly matched?

(1) Brown spot of rice	Helminthosporium oryzae
(2) Karnal bunt of wheat	Neovossia indica
(3) Bunt of rice	Neovossia horrida
(4) Hill bunt of wheat	Ustilago tritici

Select the correct answer using the codes given below:

CODES :

(a) 2, 3 and 4
(b) 1, 2 and 4
(c) 1, 3 and 4
(d) 1, 2 and 3

64. Loose smut of wheat can be effectively controlled by
(a) crop rotation
(b) soil treatment with non-systemic fungicides
(c) seed treatment with systemic fungicides
(d) spraying the crop with fungicides

65. Which one of the following correctly defines the period between inoculation and appearance of the first disease symptom?
(a) Penetration period
(b) Latent period
(c) Incubation period
(d) Infection period

66. Match List-I (Casual agent) with List-II (Disease caused) and Select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Virus	1. Sesamum phyllody
B. Mycoplasma	2. Potato spindle tuber

C. Fungus	3. Yellow vein mosaic of okra
D. Viroid	4. Downy mildew of bajra

CODES :

(a)	A	B	C	D
	1	3	2	4
(b)	A	B	C	D
	3	1	4	2
(c)	A	B	C	D
	3	1	2	4
(d)	A	B	C	D
	1	3	4	2

67. The two important diseases of sugarcane would include
(a) little leaf and bacterial wilt
(b) red rot and grassy shoot
(c) red rot and bunt
(d) bakanae disease and stem canker

68. Which one of the following statements correctly defines economic threshold level?
(a) The pest population level at which control measure should be taken to prevent the pest population from reaching economic injury level
(b) The lowest pest population density that will cause economic damage
(c) The optimum pest population density that will cause economic damage
(d) The pest population level at which application of pest control measures will be uneconomic

69. Which one of the following statements correctly defines the "alternate host" of a pathogen/parasite?
(a) A host on which a parasite attacks simultaneously with the main host
(b) A host which grows in alternate season or year
(c) One of the two kinds of hosts on which a parasitic fungus develops to complete its life cycle
(d) A host on which, the parasite does not attack in normal conditions

70. Which one of the following is the best method of controlling ear cockle disease of wheat?
(a) Application of solar heat
(b) Mechanical separation of infected seed by floatation
(c) Application of balanced dose of fertilizer
(d) Treatment of seed with pesticide

71. What is the chronological order in which the following organizations were established by Govt. of India?
    1. Locust warning and control organization
    2. Directorate of Plant Protection, Quarantine and Storage
    3. Zoological Survey of India

    Select the correct answer using the codes given below:

    CODES :

    (a) 1, 3, 2 (b) 3, 2, 1
    (c) 3, 1, 2 (d) 2, 1, 3

72. Mycoplasma is sensitive to
    (a) pencillin
    (b) bavistin
    (c) tetracycline
    (d) calixin

73. Which of the following come under the category of cultural control of insects?
    1. Change in sowing time
    2. Destruction of collateral hosts
    3. Killing effect of Sun's rays
    4. Mixed cropping

    CODES :

    (a) 1, 2, 3 and 4
    (b) 2 and 4
    (c) 1, 2 and 4
    (d) 1 and 2

74. Which one of the following can be classified as autocidal technique of insect control?
    (a) Introduction of bio-agents
    (b) Evolving resistant cultivars
    (c) Use of insect growth regulators
    (d) Release of sterile males

75. Which one of the following sprayers requires only one-third of the quantity of water while keeping the same quantity of active ingredient of the pesticide per hectare?
    (a) Foot/pedal sprayer
    (b) Mist blower
    (c) Rocking sprayer
    (d) Knapsack/backpack sprayer

76. Which one of the following sprayers would require the LOWEST volume of spray solution to cover a hectare of rice crop?
(a) Power sprayer
(b) Foot sprayer
(c) Knapsack sprayer
(d) Hand sprayer

77. The quantity of liquid insecticide with 25% active ingredient required for preparing 500 litres of the spray fluid of 0.25% strength is
(a) 1.25 litre
(b) 2.5 litre
(c) 5.0 litre
(d) 10 litre

78. Assertion (A) : Both nymphs and adults of an insect species have the same type of mouth parts.
Reason (R) : Such species lack completely metamorphosis.

79. Assertion (A) : For successful farming , pest must be controlled.
Reason (R) : All insects are crop pests.

80. Assertion (A) : The pump of a pneumatic or compression sprayer is required to be operated continuously while spraying.
Reason (R) : Initial operation of the pump develops certain amount of pressure on the spray fluid within the tank.

81. Entry of potassium ions into root hair in soils having a low potassium ion content in the soil is mediated through
(a) ion exchange mechanism
(b) mass flow phenomenon
(c) Donnan equilibrium process
(d) utilisation of metabolic energy

82. Consider the following statements:
According to cohesion theory for the ascent of sap, water moves from the roots through the stems to the leaves in tall trees because of
(1) forces of root pressure

(2) the gradient in decreasing water potentials from the soil, through the plant to the leaves
(3) forces of adhesion of water to cell walls, especially in the leaves
(4) forces of cohesion between water molecules

Of these statements
(a) 1, 2 and 3 are correct
(b) 2, 3 and 4 are correct
(c) 1, 3 and 4 are correct
(d) 1, 2 and 4 are correct

83. Which one of the following physiological processes requires close coordination of three different organelles such as mitochondria, chloroplast and peroxisome?
(a) Photosynthesis
(b) Photorespiration
(c) Respiration
(d) Protein synthesis

84. Which of the following are characteristic of C_4 plants?
(1) There are two CO_2 acceptors, namely PEP and RuBP.
(2) RuBP carboxylase is present in the mesophyll cells.
(3) The first stable product is a 4-carbon compound.
(4) Oxygen does not have any inhibitory effect on the process.

Select the correct answer using the codes given below:
CODES:
(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 1, 2 and 3 (d) 2, 3 and 4

85. Which one of the following is a set of high energy products of the light reaction of photosynthesis that are used in dark reaction?
(a) ATP and plastocynine
(b) ATP and NADP
(c) ATP and (NADPH + H^+)
(d) Plastoquinone and ferridoxine

86. Which of the following pairs of hormones and bioassay techniques are correctly matched?
(1) Cytokinin — Radish cotyledon test
(2) Gibberellic acid — Rice second leaf test
(3) Indole-3-acetic acid — Coleoptile curvature test

Select the correct answer using the codes given below:

(a) 2 and 3 (b) 1 and 2

(c) 1 and 3 (d) 1, 2 and 3

87. Which of the following statements about carotenoids are correct?

(1) Carotenoids present in coleoptile affect the destruction of auxin by light.

(2) Pollens generally carried by insects for pollination contain carotenes whereas carotenoid pigments are rarely detected in pollens of wind pollinated flowers.

(3) They cause a suitable drop in light intensity leading to a gradient of increasing auxin concentration from the lighted side to the darker side.

(4) They absorb blue light to produce phototropic curvature in oat coleoptile in phycomyces and also in certain blue-green algae.

Select the correct answer using the codes given below:

CODES :

(a) 2, 3 and 4

(b) 1, 2 and 4

(c) 1, 3 and 4

(d) 1, 2 and 3

88. Which of the following structures help the fungi to survive under adverse conditions?

(1) Zoospores

(2) Chalmydospores

(3) Sclerotia

(4) Conidiospores

Select the correct answer using the codes given below:

CODES :

(a) 3 and 4

(b) 2 and 4

(c) 1, 2 and 3

(d) 2 and 3

89. Modification of floral parts into leafy structures by pathogenic infection is called

(a) hyperplasia

(b) hypertrophy

(c) phyllody

(d) witch's broom

90. Match List-I (Diceases) with List-II (Diceases incitants) and Select the correct answer using the codes given below the lists:

List-I	**List-II**
A. Karnal bunt of wheat	1. Sclerospora graminicola
B. Late blight of potato	2. Tilletia indica
C. Flax rust	3. Phytophthora infestans
D. Downy mildew of bajra	4. Melamspora lini

CODES :

(a)	A	B	C	D
	3	2	4	1
(b)	A	B	C	D
	2	3	4	1
(c)	A	B	C	D
	2	3	1	4
(d)	A	B	C	D
	3	2	1	4

91. Consider the following statements:
"Gundhi bug" causes damage to paddy crop by
(1) sucking juice from the developing grains
(2) sucking juice from the leaves
(3) sucking juice from the culm
(4) affecting the quality and quantity of grain
Of these statements
(a) 2 and 4 are correct
(b) 1, 3 and 4 are correct
(c) 2 alone is correct
(d) 1 alone is correct

92. Two of the more important diseases of potato whose spread in India has been successfully restricted through plant quarantine measures include
(a) Brown rot and late blight
(b) Wart and golden nematode
(c) Ring rot and mosaic
(d) Bacterial wilt and charcoal rot

93. Severe incidence of red hairy caterpillar occurs under which one of the following sets of conditions?
(a) High temperature and high soil moisture
(b) High temperature and low soil moisture
(c) Low temperature and high soil moisture
(d) Low temperature and low soil moisture

94. Match List-I with List-II and Select the correct answer using the codes given below the lists:

List-I (Pathogenic genera of fungi)	List-II (Symptoms and effects)
A. Cystopas	1. Red rust
B. Protomyces	2. Green ear
C. Sclerospora	3. White rust
D. Taphrina	4. Leaf curl
	5. Stem gall

CODES :

	A	B	C	D
(a)	1	5	2	4
(b)	3	5	4	1
(c)	4	1	2	3
(d)	3	5	2	4

95. Consider the following stages:
(1) Spore germination
(2) Embryo infection
(3) Spore on flower stigma
(4) Infected grains
The correct sequence of these stages in the development of loose smut disease in wheat is
(a) 3, 1, 4, 2 (b) 1, 3, 4, 2
(c) 1, 3, 2, 4 (d) 3, 1, 2, 4

96. Which one of the following is the vector for yellow vein mosaic of bhindi (okra)?
(a) Brown plant hopper (b) Green plant hopper
(c) Aphids (d) White files

97. Consider the following steps:
(1) Sampling
(2) Surveillance
(3) Control stretegy
The correct sequence of these steps in the management of pests and diseases is
(a) 1, 2, 3 (b) 2, 1, 3
(c) 2, 3, 1 (d) 1, 3, 2

98. Which one of the following statements correctly defines systemic insecticides?
   (a) An insecticide which enters into the system of insects
   (b) An insecticide which is absorbed into the plant system
   (c) An insecticide which is absorbed and translocated in the system of the plant
   (d) An insecticide that processes translaminar activity
99. Which one of the following groups consists of systemic fungicide?
   (a) Bavistin, Topsin-M, Captan
   (b) Plantvax, Emisan, Blitox
   (c) Vitavax, Bavistin, Calixin
   (d) Ziram, Plantvax, Blitox
100. Brodeaux Mixture was discovered by P.A. Millardet of France during the year, 1882 following his chance observation of a farmer's practice for protection against
   (a) Plasmopara viticola on grapevine
   (b) Uncinula necator on grapevine
   (c) Podosphaera leucotricha on apple
   (d) Venturia inequalis on apple
101. Which one of the following sprayers will cause more loss of spray droplets by drift?
   (a) Low volume sprayer
   (b) High volume sprayer
   (c) Ultra low volume sprayer
   (d) Duster
102. Which of the following would determine the quantity of spray needed per hectare while using manually operated knapsack sprayers?
   (1) Swath of spray
   (2) Walking speed of the person doing the spraying
   (3) Calibration of the sprayer
   (4) Type of nozzle

   Select the correct answer using the code given below:

   CODES :
   (a) 1, 2 and 4
   (b) 1, 2 and 3
   (c) 1, 3 and 4
   (d) 2, 3 and 4

103. Which of the following safeguards are necessary for a proper operation and maintenance of plant protection equipment?
(1) Lubrication should be followed faithfully using the specified lubricant.
(2) A multigrade motor oil should not be mixed with petrol as fuel for a 2-stroke engine.
(3) The oil and fuel should be poured separately into the tank. Select the correct answer using the code given below:

CODES :
(a) 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 1, 2 and 3

104. Which one of the following remedies is to be suggested in case of failure of a manually operated sprayer to retain pressure?
(a) Tightening of loose nuts and clamps and replacement of gaskets
(b) Tightening of the lid of the tank, replacement of the gasket, if necessary
(c) Opening the nozzle and cleaning its various parts especially the orifice
(d) Straightening the plunger rod if found bent

105. Assertion (A) : When light falls on guard cells of stomata, their osmotic potentials become more negative and they open.
Reason (R) : Light causes an increase in the transport of K^{+}ions from the accessory cells to tne guard cells.

106. Assertion (A) : In zinc deficient plants concentration of indolecetic acid in the tissues drops well before visible symptoms appear.
Reason (R) : Zinc is essential for the synthesis of tryptophan.

107. Assertion (A) : Respiratory quotient for respiration of materials rich in carbohydrates is usually about 1.
Reason (R) : Carbohydrate molecules have the same number of carbon atoms as the oxygen atoms.

108. Assertion (A) : $CoCl_2$ and $NiCl_2$ promote the vase life of chrysanthemum flowers.

Reason (R) : $CoCl_2$ and $NiCl_2$ act as anti-ethylene compounds.

109. Assertion (A) : Vitamin C requirement of human body has to be met by exogenous sources such as fruit and vegetables.

Reason (R) : Vitamin C can neither be synthesised nor stored in the human body.

110. Assertion (A) : Seed treatment with chlorpyriphos is done in groundnut.

Reason (R) : It helps in controlling white grub.

111. Assertion (A) : Integrated pest management is the best way of controlling disease and pests of crop plants.

Reason (R) : This ensures that all the insects and pathogens are killed effectively.

112. Assertion (A) : Survey and surveillance is the back-bone of integrated pest control.

Reason (R) : Integrated pest control can be achieved by integrating chemical, biological, cultural, regulatory and mechanical methods of pest control.

113. Which one of the following chemicals is used to treat seed potato to break its dormancy?
(a) Ethral (b) Thiourea
(c) Indole acetic acid (d) Naphthalene acetic acid

114. Tick, which disease is commonly found in Jowar fields?
(a) Wilt
(b) Blast
(c) Leaf spot
(d) Grain smut

115. Citrus species resistant to canker is:
(a) Citrus aurantifolia
(b) Citrus limonia
(c) Citrus paradisi
(d) Citrus karna

116. The "little leaf" disease of brinjal is caused by:
(a) Fungus
(b) Bacteria
(c) Nutrition
(d) None of the above
117. Mycorrhizal association is found in:
(a) Papaya
(b) Litchi
(c) Bael
(d) Ber
118. The most commonly used plant growth regulator for rooting of cuttings is:
(a) IBA
(b) Cycocel
(c) Ethephone
(d) GA_3
119. The casual organism of 'red rot' a fungal disease of sugar-cane, is present in:
(a) Soil
(b) Climate
(c) Seed (planting material)
(d) Virus
120. The most suitable chemical for seed treatment of wheat against 'Kernel bunt' is:
(a) B. H. C.
(b) Agrosan G.N.
(c) Vitavax
(d) Captan
121. The fruit-fly belongs to:
(a) Phycitidae
(b) Tephritidae
(c) Techinidae
(d) Coccinellidae
122. The insecticide act was passed by Parliament in the year:
(a) 1973
(b) 1965
(c) 1968
(d) 1972

13

123. The locust deposits its eggs:
(a) On lower surface of leaves
(b) In the soil
(c) In the tender parts of a twig
(d) In dry grasses

124. The rate of fumigation of EDB per quintal grain is:
(a) 1 ml.
(b) 3 ml.
(c) 6 ml.
(d) 10 ml. 1

125. Hopper burn is the result of attack of the following insect pest:
(a) Grasshopper
(b) Sugarcane leafhopper
(c) Brown planthopper
(d) Green leafhopper

126. Which of the following insecticide is safest for use? 1
(a) Methyl parathion
(b) Carbaryl
(c) Phosphomidan
(d) DDT

127. Who was the first Plant Protection Advisor to Govt. of India? 1
(a) Dr. Sardar Singh
(b) Dr. S. Pradhan
(c) Dr. M.L. Roonwal
(d) Dr. H.S. Pruthi

128. White grub is the pest of:
(a) Rice
(b) Wheat
(c) Groundnut
(d) Mustard

129. Integrated pest management refers to:
(a) It is the use of zero pesticides
(b) Use of zero tillage
(c) Use of zero fertilizers
(d) Management of all above judiciously

130. The deficiency of thiamine (B_1) in human body causes:
(a) Night-blindness
(b) Beri-Beri
(c) Pellagra
(d) Scurvy

131. Dissemination of plant pathogens take place only by:
(a) wind
(b) wind and water
(c) wind, water and soil
(d) wind, water, soil and insects

132. One of the factors causing malformation of mango is:
(a) Fungus
(b) Nematodes
(c) Virus
(d) Bacteria

133. The zinc deficiency in paddy plants causes:
(a) Blight disease
(b) Ergot disease
(c) Smut disease
(d) Khaira disease

134. Panama wilt is a disease of:
(a) Apple
(b) Banana
(c) Pear
(d) Peach

135. The most convenient and safer chemical to control stored grain insects in rural areas is:
(a) E D B
(b) Celphos
(c) D D T
(d) Naphthalene ball

136. Insects with sucking type of mouth parts need following group of insecticides for effective controll:
(a) Stomach poisons
(b) Systemic poisons
(c) Contact poisons
(d) Fumigants

137. Insecticides under Intergrated Control System are applied at which one of the following stage:
(a) General equilibrium level
(b) Economic threshold level
(c) Economic injury level
(d) Total loss level

138. Cynogas pump is a:
   (a) Sprayer
   (b) Duster
   (c) Flame thrower
   (d) Fumigator

139. Which one of the following is the richest source of Vitamin 'A':
   (a) Banana
   (b) Wheat
   (c) Rice
   (d) Mango

140. 'Aphids' in mustard can be controlled by the use of:
   (a) Malathion
   (b) Vitavex
   (c) Thiram
   (d) Dithane-Z

141. Which one of the following is NOT correctly matched:

	Crop	*Disease*
(a)	Potato	Blight
(b)	Wheat	Smut
(c)	Jowar	Ergot
(d)	Til	Phyllody

142. Which one is an insect trap crop:
   (a) Arhar
   (b) Paddy
   (c) Bhindi
   (d) Potato

143. The most abundant acid in grape is:
   (a) Tartaric acid
   (b) Citric acid
   (c) Ascorbic acid
   (d) Gallic acid

144. Which is the most effective light in photosynthesis:
   (a) Blue
   (b) Green
   (c) Yellow
   (d) Red

145. In glycolysis, conversion of a molecule of glucose to two molecules of Pyruvic acid results in a net gain of:
(a) 8 ATP molecules
(b) 38 ATP molecules
(c) 2 ATP molecules
(d) 36 ATP molecules

146. The number of ATP that forms during the Kreb's cycle of respiration will be:
(a) 8
(b) 15
(c) 22
(d) 30

147. Nematodes are:
(a) Symbiotic nitrogen fixers
(b) Blue green algae
(c) Insects
(d) Plant pathogens

148. Which one of the following is a growth retardant:
(a) 2, 4, 5-T
(b) Cycocel
(c) CEPA
(d) TIBA

149. The correct pair is:
(a) Rice-white grub
(b) Potato-white ants
(c) Sugarcane-weevil
(d) Gram-pod borer

150. Pollen besket is found in the hind legs of:
(a) Termite
(b) Honeybee
(c) Ant
(d) Butterfly

151. Why insecticidal spraying should be avoided when crops are in flowering stage:
(a) to prevent flower dropping
(b) to facilitate proper fruit setting
(c) to protect bees
(d) to prevent insecticidal residues

152. Which one is the anticoagulant:
   (a) Zinc phosphide
   (b) Aluminium phosphide
   (c) Magnesium oxide
   (d) Bromodiolone
153. Under intigrated system of insect control we integrate:
   (a) Cultural and biological methods
   (b) Biological and legal methods
   (c) Physical and chemical methods
   (d) All types of methods
154. The least toxic insecticides to human beings belong to the following group:
   (a) organo chlorines
   (b) organo phosphates
   (c) carbamates
   (d) synthetic pyrethroids
155. Yellow mosaic in soyabean is spread by:
   (a) Seeds
   (b) Soils
   (c) Air
   (d) White fly
156. Loose smut of wheat is controlled by:
   (a) Seed treatment
   (b) Soil sterilization
   (c) Crop rotation
   (d) Thiram spray on crop
157. Systemic insecticide used to control pests is:
   (a) Endosulphan
   (b) Chlorpyriphos
   (c) Phosphamidon
   (d) Quinophos
158. Canker disease of citrus is caused by:
   (a) Bacteria
   (b) Fungus
   (c) Virus
   (d) Nematodes

159. 'Tungru' is a viral disease of:
(a) Rice
(b) Citrus
(c) Wheat
(d) Tobacco

160. Which one of the following is not correctly matched:

	Crop	Disease
(a)	Mustard	Alternaria blight
(b)	Urd (Black gram)	Sterility mosaic
(c)	Soyabean	Yellow mosaic
(d)	Groundnut	Bud necrosis

161. Loss of electron is known as:
(a) Oxidation
(b) Reduction
(c) Catalysis
(d) Hydrolysis

162. What is the correct sequence in which the following events occur during pathogenesis or disease cycle?
(1) Penetration
(2) Colonization
(3) Infection
(4) Exit of pathogen
Select the correct answer from the codes given below:

(a)	1,	3,	2,	4
(b)	1,	2,	3,	4
(c)	3,	1,	2,	4
(d)	4,	2,	3,	1

163. Which one of the following is the cause of "spreading decline" of citrus?
(a) Citrus nematode (Tylenchulus semipentrans)
(b) Burrowing nematode (Radopholus similis)
(c) Fungal diseases
(d) Nutritional deficiency

164. The incidence of "White grubs" is heavy in:
(a) heavily water-logged fields
(b) dry fields having sandy-loam soil
(c) dry fields of heavy clay soil
(d) desert land having little vegetation

165. Which one of the following helps in maintaining the shape of nematodes?
   (a) Pseudocoelomic fluid
   (b) Cuticle and muscles
   (c) Pseudocoelome
   (d) Annulation of cuticle

166. Green leaf hopper of paddy is the primary vector of
   (a) tungro disease
   (b) sheath rot disease
   (c) kresek disease
   (d) ufra disease

167. Bacterial leaf blight of rice caused by Xanthomonas oryzae can be indentified by
   (a) wilting of the plant
   (b) yellowing of leaves
   (c) 'ooze test'
   (d) defoliation

168. White ear-head in paddy is caused by
   (a) gall fly
   (b) green leaf hopper
   (c) yellow stem borer
   (d) stink bug

169. Match List-I with List-II and select the correct answer using the codes given below the lists:

	List-I *(contribution)*	**List-II** *(Scientist)*
A.	A fungus is the cause of wheat-bunt disease	1. K.C. Mehta
B.	Modern techniques of growing microorganisms in pure culture	2. T.O. Diener
C.	Discovery of disease cycle of wheat rust in India before 1947	3. Prevost
D.	Introduced the term 'viroid'	4. Brefeld

CODES :

	A	B	C	D
(a)	1	2	3	4
(b)	2	3	1	4

(c) A B C D
3 4 1 2

(d) A B C D
4 1 2 3

170. Which one of the following types of spraying is best done by manually operated knapsack sprayer having flat-fan nozzle?
(a) High volume
(b) Low volume
(c) Ultra low volume
(d) Semi-low volume

171. Domestic quarantine exists in India against
(1) Panama disease of banana
(2) Potato root eelworm
(3) San Jose scale
(4) Sugarbeet eelworm
Select the correct answer from the codes given below
Codes:
(a) 1 and 4
(b) 1 and 2
(c) 2 and 3
(d) 2, 3 and 4

172. The spray is classified as aerosol when average droplet size (volume median diameter) is
(1) 50 m
(2) 50 - 100 m
(3) 100 - 200 m
(4) 200 - 400 m

173. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I *(Equipments)*	**List-II** *(Insecticides/pesticides)*
A. High volume sprayer	1. Dusts
B. Blowers	2. Wettable powder
C. Back pack sprayer	3. Liquids
D. Rocker sprayer	4. Emulsions

CODES :

(a) A B C D
1 2 4 3

(b) A B C D
2 1 3 4

(c) A B C D
3 4 1 2

(d) A B C D
4 3 2 1

174. Pneumatic sprayers have been used in pest control for many years. A pneumatic sprayer
(a) operates using wind or air
(b) contains poisonous pesticide
(c) is a knapsack type sprayer
(d) operates automatically

175. Solar energy treatment of wheat seed against loose smut was given by
(a) Jensen in 1889
(b) Swingle in 1892
(c) Luthra and Sattar in 1934
(d) Freeman and Johnson in 1909

176. Which one of the following equipments can be effectively used for spraying an orchard crop?
(a) Barrel pump
(b) Sikar pump
(c) Foot sprayer
(d) Heli sprayer

177. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I *(Equipments)*	**List-II** *(Mode of Use)*
A. Rotary duster	1. Ultra low volume (ULV) formulation
B. Package duster	2. Small scale use
C. Heli sprayer	3. Feeding brush
D. Pedal pump	4. High volume (HV) spray

CODES :

(a) A B C D
2 1 4 3

(b) A B C D
3 2 1 4

	A	B	C	D
(c)	1	3	4	2
(d)	4	3	2	1

178. In case of rotary type of duster the air current is developed by
   (a) bellows
   (b) fans
   (c) self-propelling jacket
   (d) self-propelling blades
179. Which one of the following can be classified as hydraulic energy sprayer?
   (a) kanpsack mist blower
   (b) controlled drip applicator sprayer
   (c) knapsack sprayer
   (d) wheel barrow sprayer
180. Assertion (A) : All pests are NOT insects.
   Reason (R) : There are a number of helpful and productive insects.
181. Assertion (A) : A multigrade motor oil should be mixed with petrol used as fuel for a 2-stroke engine for motorized knapsack sprayer.
   Reason (R) : Multigrade motor oils are blended from different grades of lubricating oils and are suitable for engines subjected to great temperature variations.
182. Assertion (A) : Smut diseases (loose and covered smut) of wheat are seed-borne and can be effectively controlled by treating the seeds with a systemic fungicide.
   Reason (R) : Systemic fungicide used (at the recommended dose) have no adverse effect on seed germination.
183. Match List-I (Crop) with List-II (problems associated with the crop) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Mango	1. Poor fruit set
B. Grape	2. Malformation

C. Pineapple — 3. Powdery mildew
D. Custard apple — 4. Fasciation

CODES :

(a)	A	B	C	D
	3	2	4	1
(b)	A	B	C	D
	2	3	4	1
(c)	A	B	C	D
	3	2	1	4
(d)	A	B	C	D
	2	3	1	4

184. Which one of the following is the correct sequence in the ethylene biosynthesis pathway?
(a) Methionine, ACC, SAM, Ethylene
(b) Methionine, SAM, ACC, Ethylene
(c) ACC, Methionine, SAM, Ethylene
(d) ACC, SAM, Methionine, Ethylene

185. Rhizoctonia solani causes a tuber borne disease of potato, called
(a) Black scurf
(b) Charcoal rot
(c) Common scab
(d) Powdery scab

186. What is the correct sequence of the following historical plant disease epiphytotics?
(1) Coffee rust epiphytotics in Ceylon
(2) Potato late blight epiphytotics in Ireland
(3) Rice leaf spot (Helminthosporium) epiphytotics in Bengal.
Select the correct answer using the codes given below:
CODES :
(a) 1, 3, 2
(b) 1, 2, 3
(c) 3, 1, 2
(d) 2, 1, 3

187. Which of the following pairs is correctly matched?
(a) White fly — Yellow mosaic of green gram
(b) Aphid — Mango malformation
(c) Thrip — Groundnut tikka disease
(d) Brown plant hopper — Blast of rice

188. Consider the following stages in the life cycle of the fungus that causes black or stem rust of wheat:
(a) Telia
(b) Uredia
(c) Spermogonia
(d) Aecia
The correct sequence of these stages in the life cycle of the fungus is
(a) 1, 2, 3, 4
(b) 2, 1, 4, 3
(c) 2, 1, 3, 4
(d) 1, 2, 4, 3

189. Which one of the following is the cause of black heart of potato?
(a) Copper deficiency
(b) Boron deficiency
(c) Potassium deficiency
(d) Oxygen deficiency

190. Match List-I with List-II and select the correct answer using the codes given below the lists:

	List-I	**List-II**
	(Diseases)	*(Genera of fungi)*
A.	Bunts	1. Plasmopara, Bremia
B.	Downy Mildews	2. Neovossia, Tilletia
C.	Rusts	3.Sphacelotheca, Tolyposporium
D.	Wilts	4. Melampsora, Uromyces

CODES:

(a)	A	B	C	D
	2	1	5	4
(b)	A	B	C	D
	2	4	3	1
(c)	A	B	C	D
	3	2	1	4
(d)	A	B	C	D
	4	1	5	3

191. Rice-wheat cropping system is prone to some serious diseases which can affect both the crops. Which one of the following rice diseases can seriously damage the wheat crop in India, if virulent strains of the pathogen are introduced?

(a) Blast
(b) Bacterial leaf blight
(c) Brown spot
(d) Foolish seedling disease

197.

192. Which one of the following fungicides is ineffective against loose smut of wheat?
(a) Baytan
(b) Bavistin 50W
(c) Thiram
(d) Vitacax 75W

193. Which one of the following types of fungicides is of greatest importance in protecting plants from fungal pathogenes?
(a) Therapeutant fungicides
(b) Eradicant fungicides
(c) Protectant fungicides
(d) Systemic fungicides

194. Which one of the following sets of abbreviations correctly designates pesticide formulation in the solid state?
(a) SD, EC and G
(b) SD, EC and WP
(c) SD, G and WP
(d) EC, G and WP

195. Which one of the following pesticides in banned in India?
(a) Endrin
(b) BHC
(c) Malathion
(d) Endosulphan

196. Which of the following would cause development of insect resistance to insecticides?
(1) Sub-lethal dose of the insecticide applied
(2) Repetitive use of the same insecticide
(3) Host plant factors
(4) Rigours of abiotic factors

Select the correct answer using the codes given below:

CODES:
(a) 2 and 4
(b) 1 and 2
(c) 1, 2 and 3
(d) 1, 2, 3 and 4

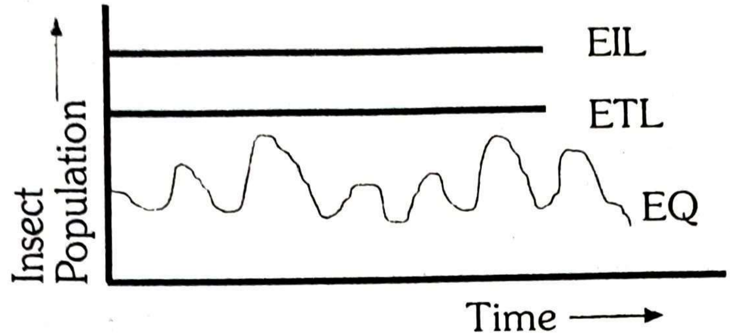
197. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I *(Pesticides of plant origin)*	**List-II** *(Sources)*
A. Neem products	1. Azadirachta indica
B. Nicotine	2. Chrysanthemum cinerariaefolium
C. Pyrethrum	3. Derris elliptica
D. Rotenone	4. Nicotiana rustica

CODES :

	A	B	C	D
(a)	4	1	2	3
(b)	1	4	2	3
(c)	1	4	3	2
(d)	4	1	3	2

198. Consider the following statements :
Microbial pesticides like Baccilus thuringiensis (Bt) and Nuclear Polyhedrosis Viruses (NPV) are well-suited to the integrated pest management programme because
(1) the development of resistance in insects against pesticides is nil.
(2) there is much less possibility of resistance development against such pesticides.
(3) they are safe and ecofriendly.
(4) they are inexpensive.
Of these statements
(a) 1, 2, 3 and 4 are correct
(b) 2, 3 and 4 are correct
(c) 3 and 4 are correct
(d) 2 and 3 are correct

199. 

Equilibrium position (EQ), Economic Threshold Level (ETL) and Economic Injury Level (EIL) of an insect pest attacking a particular crop is shown in the above figure. The correct control strategy for this situation would be
(a) Spray insecticide at EIL
(b) Spray insecticide at ETL
(c) Spray insecticide below ETL
(d) None of the above as insecticide spray is not required.

200. Which one of the following is the most suitable substance for calibrating hand sprayer before taking up spraying with pesticides?
(a) Linseed oil
(b) Mustard oil
(c) Water
(d) Kerosene oil

201. Match List-I (Name of equipment) with List-II (Types) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Battery operated CDA sprayer	1. High volume sprayer
B. Knapsack power sprayer	2. Fumigation
C. Rocking sprayer	3. Low volume sprayer
D. Soil injector	4. ULV sprayer

CODES :

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	3	4	1	2
(d)	4	3	2	1

202. What is the amount of Bavistin 50 W required to be added to 1000 litres of water to make a spray mixture of 0.05% a.i. concentration?
(a) 0.5 kg.
(b) 1.0 kg.
(c) 1.5 kg.
(d) 2.0 kg.

203. Assertiont (A) : CCC leads to stunting of plant growth.
Reason (R) : CCC inhibits endogenous synthesis of gibberellins.

204. Assertion (A) : Calcium carbide is used to hasten the ripening of mango.
Reason (R) : Calcium carbide releases acetylene which promotes fruit repening.

205. Assertion (A) : Tobacco mosaic virus (TMV) has a very wide host range.
Reason (R) : TMV has an efficient aphid vector.

206. Assertion (A) : Aircraft spraying may be done from greater heights than dusting.
Reason (R) : Spray droplets fall faster than dust particles.

207. Which of the following is a ripening hormone:
(a) Ethylene
(b) Cytokinin
(c) Auxin
(d) Gibberellin

208. The attack of pea stem fly is maximum in:
(a) September
(b) November
(c) January
(d) February

209. Powdery mildew disease is a serious problem in which of the following crops:
(a) Capsicum
(b) Okra
(c) Cucurbits
(d) Pea

210. The maximum CO_2 concentration is found at high intensity of :
(a) 2500-5000 foot candles
(b) 6000-7500 foot candles
(c) 1000-2000 foot candlles
(d) 2150-2450 foot candles
211. Which of the following is controlled by Gibberellin acid :
(a) Fruit fall
(b) Ripening of fruits
(c) Vegetative growth
(d) Prevention of the loss of flowers
212. Auxin is :
(a) An Enzyme
(b) A Vitamin
(c) A Hormone
(d) A Protein
213. The normal eye colour in *Drosophila* is red. But mutants occur having white eye and also different shades ranging between white and red which are all recessive to red, while white colour is recessive to all others. This phenomenon is due to :
(a) Pseudodominance
(b) Pseudoallelism
(c) Co-dominance
(d) Polygenesis
214. Albinism in plants is associated with :
(a) Epistasis
(b) Recessive lethal
(c) Dominant lethal
(d) Chromosome duplication
215. Polygenes affecting the same trait, with each enhancing the phenotype are termed as :
(a) Amnions
(b) Alcaptonuria
(c) Allosteric effects
(d) Additive factors
216. In sweetpeas *(Lathyrus odoratus)* gene C or P alone produces white flower, whereas both C and P are needed to

produce purple-coloure-flower. In a particular cross between two white-flowered plants, the offsprings were one-half purple and one-half white. The possible genotypes of the parents is:

(a) $C_cP_p \times ccP_p$

(b) $CC_{pp} \times ccPP$

(c) $ccP_p \times CC_{PP}$

(d) $C_{cpp} \times ccP_P$

217. Match List-I (Crop plants) with List-II (ploidy levels of the plants) and select the correct answer using the codes given below the lists :

List-I	List-II
A. Bread wheat	1. Diploid
B. Pea	2. Triploid
C. Sea-island cotton	3. Allo-hexaploid
D. Banana	4. Allo-tetraploid

CODES :

	A	B	C	D
(a)	2	1	4	3
(b)	3	1	4	2
(c)	2	4	3	1
(d)	3	4	1	2

218. Which of the following pairs of definitions and terms are correctly matched?

(1) The immediate effect of Pollen on the character of endosperm — Xenia

(2) A cytoplasmic-borne unit of heredity — Plasmogene

(3) A haploid chromosome in an otherwise normal diploid individual — Monosome

Select the correct answer using the codes given below:

CODES.

(a) 1, 2 and 3
(b) 1 and 2
(c) 1 and 3
(d) 2 and 3

219. The condition in which a single gene influences more than one trait is known as
(a) Epistasis
(b) Pleiotropy
(c) Polarity mutation
(d) Phenocopy

220. Which of the following type (s) of male sterility is are used in commercial seed production of double cross hybrid maize?
(a) Cytoplasmic alone
(b) Genetic alone
(c) Cytoplasmic and genetic
(d) Cytoplasmic and genetic with restorers

221. The composite variety has an advantage over the hybrid variety in respect of :
(a) Yield
(b) Synthesis
(c) Homogeneity
(d) Seed production

222. Consider the following statements :
(1) Wheat is self-pollinated
(2) Inbreeding depression is expected to be more pronounced in rapeseed than in mustard.
(3) F_1 seeds alone are used for cultivation in both hybrid and composite varieties.
(4) Hybrid vigour is expected to be more pronounced in bajra than in Bengal gram.

Of these statements.
(a) 1, 2, 3 and 4 are correct
(b) 1 and 2 are correct
(c) 2, 3 and 4 are correct
(d) 1, 3 and 4 are correct

223. Consider the following statements :
Triticale
(1) Is a cross between species of two different genera Secale cereale (2n = 14) and Triticum vulgare (2n = 42).
(2) Is amphidiploid with 56 chromosomes.
(3) Has high degree of Fertility.
Of these statements
(a) 1 and 2 are correct
(b) 1 and 3 are correct
(c) 2 and 3 are correct
(d) 1, 2 and 3 are correct

224. Efforts are on in the Mexican wheat breeding programme to develop multiline varieties for greater genetic diversification to reduce rust infestation. What is the correct sequence of the following steps in the procedure adopted to develop a multiline variety?
(1) Choosing a commercially acceptable variety for the recurrent parent.
(2) Introducing concurrently, different genes for rust resistance into the recurrent variety by separate backcross programme.
(3) Compositing 5 to 10 different backcross derived lines of the recurrent variety each with a different gene for rust resistance.
(4) Increasing the composite and growing as a commercial variety.
Select the correct answer using the codes given below :
CODES :
(a) 3, 1, 2, 4
(b) 1, 3, 2, 4
(c) 1, 2, 3, 4
(d) 3, 2, 1, 4

225. The components of synthetic population would have already been tested for
(a) Specific combining ability
(b) genetic advance
(c) general combining ability
(d) both general and specific combining ability.

226. The popular variety, Ganga Safed-2 of maize is a
(a) Single cross hybrid
(b) Double cross hybrid
(c) 3-way cross hybrid
(d) Double topcross hybrid

227. The mutation induced nullisomic variety of sugarcane is
(a) Co - 8504
(b) Co - 8153
(c) Co - 527
(d) Co - 8152

228. In pedigree method of breeding, single plants are selected in which one of the following generations?
(a) F_5
(b) F_3
(c) F_2
(d) F_1

229. Pusa Delicious a gynodioecious variety of papaya has which of the following sex forms?
(1) Pistillate
(2) Staminate
(3) Hermaphrodite
Select the correct answer using the codes given below :
CODES :
(a) 1 and 2
(b) 1 and 3
(c) 2 and 3
(d) 1, 2 and 3

230. Which one of the following genetic factors is responsible for poor fruit set in custard apple?
(a) Heterostyly
(b) Dioecious nature
(c) Dichogamy
(d) Self-incompatibility

Directions : The following Twelve items consist of two statements, one labelled the 'Assertion A' and the other labelled the 'Reason R'. You are to examine these two statements carefully and decide if the Assertion A and Reason R are individually true and if so, whether the Reason is a correct explanation of the Assertion. Select your

answers to these items using the codes given below and mark your answer sheet accordingly.

CODES :

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

231. Assertion (A) : The expected genetic gain as calculated by the formula

$$Gs = K.\ \sigma_p.H$$

is applicable to a mixture of pureliness or clones, but it is not applicable to segregating generations.

Reason (R) : Purelines or clones give rise to progenies which are identical in genotype with the parent family and the plants in segregating generations are likely to be heterozygous for a few or several genes.

232. Assertion (A) : The F_1 hybrids of Solanum melongena Muktakeshi × Banaras giant and Muktakeshi × Pusa kranti exhibited increase over better parent as regards yield.

Reason (R) : Exploitation of hybrid vigour has attained considerable importance in most of the vegetables.

233. When a group of phenotypically similar appearing plants is selected and harvested and their seeds are bulked, the process is known as
(a) Pedigree breeding
(b) Mass selection
(c) Bulk method of breeding
(d) Pure line selection

234. The effect of the genotype of the pollen grain on the phenotype of the seed is termed as
(a) apospory
(b) pollenia
(c) endopolyploidy
(d) xenia

235. Clistogamy encourages
(a) Self-pollination
(b) Cross pollination
(c) apomixis
(d) inbreeding depression

236. Exchange of genetic material takes place between non-sister chromatids of homologous chromosomes during the
(a) Four strand stage in prophase I
(b) Two strand stage in prophase I
(c) Metaphase I stage in meiosis
(d) Two strand stage in prophase II

237. Heterosis over the better parent is called
(a) Relative heterosis
(b) Standard heterosis
(c) Pseudoheterosis
(d) Heterobeltiosis

238. Which of the following are the base pairs of a DNA molecule?
(1) Adenine - thymine
(2) Cystine - guanine
(3) Adenine - uracil
(4) Thymine - guanine
Select the correct answer using the codes given below :
CODES :
(a) 1 and 4
(b) 3 and 4
(c) 1 and 2
(d) 2 and 3

239. DNA exists as a double helix as a result of hydrogen bonding between.
(a) Sugar molecules
(b) Phosphate groups
(c) Nucleohistones
(d) Nucleosides

240. When a plant heterozygous for two given characters Tt Rr, both of them are completely dominant, is self-pollinated, the resulting progeny will consist of
(a) Six phenotypes
(b) Four phenotypes

(c) Three phenotypes
(d) Two phenotypes

241. Sterility is most pronounced in the F_1 generation following
(a) Intervarietal hybridization
(b) Intravarietal hybridization
(c) Intraspecific hybridization
(d) Interspecific hybridization

242. Which one of the following categories of seeds is the farmer expected to buy afresh everytime?
(a) Variety
(b) Hybrid
(c) Synthetic
(d) Composite

243. Hybrid seeds can be produced through open pollination with the use of
(a) Inbreds
(b) Clones
(c) Pure lines
(d) Male sterile lines

244. Sterility/incompatibility of distant crosses can be overcome to produce hybrids, by
(a) Pollen culture
(b) Anther culture
(c) Explant culture
(d) Embryo culture

245. A three way cross in maize is defined as a cross between a single cross and
(a) An open pollinated variety
(b) Synthetic
(c) An inbred line
(d) Another single cross

246. The production of double cross hybrid in maize was first suggested by
(a) Shull
(b) East
(c) Jones
(d) Hull

247. Which one of the following improved crop varieties has been evolved through induced mutagenesis?
(a) IR-36 variety of rice
(b) Aruna variety of castor
(c) UP-262 variety of wheat
(d) Varuna variety of mustard

248. The sugarcane (Saccharum officinarum 2n = 80) variety are cytologically.
(a) Autopolyploids
(b) Octoploids
(c) Segmental polyploids
(d) Complex polyploids

249. A time honoured sugarcane variety (wonder cane) is
(a) Co 975
(b) Co 7508
(c) Co 6907
(d) Co 419

250. The first sunflower hybrid developed in India is
(a) MSFH-8
(b) KBSH-1
(c) APSH-11
(d) BSH-1

251. In maize, 2n chromosome number = 20. The number of chromosomes in
(1) Endosperm cells
(2) Pollen mother cell
(3) Pollen tube nucleus and
(4) Root-tip cells
Would be respectively

	1	2	3	4
(a)	30	20	20	10
(b)	20	10	20	20
(c)	20	20	10	20
(d)	30	20	10	20

252. Consider the following statements :
The formation of a loop during pachytene indicates
(1) Translocation
(2) Deficiency
(3) Inversion
(4) Duplication

Of these statements
(a) 1 and 3 are correct
(b) 2 and 4 are correct
(c) 1, 2 and 3 are correct
(d) 2, 3 and 4 are correct

253. Genotypex x Environment interaction would take place when there is/are
(a) One genotype and two environments
(b) Two genotypes and one environment
(c) Three genotypes and one environment
(d) Two or more genotypes and two or more environments

254. The situation where an egg cell is developed into an embryo without fertilization, is described as
(a) Apomixis
(b) parthenocarpy
(c) sexual reproduction
(d) Parthenogenesis

255. An anticodon is a sequence of three nitrogenous bases found on
(a) DNA
(b) Messenger RNA
(c) Ribosomal RNA
(d) Transfer RNA

256. What is the correct sequence of the following during the process of mitosis?
(1) The chromosomes are in their most condensed form having moved to the equatorial plane of the spindle.
(2) The centromere interacts with the spindle apparatus.
(3) The chromosomes consist of long threads paired along their entire length.
(4) Division of the cytoplasm.
(5) Sister chromatids move apart to opposite poles.
(6) The nuclear membrane breaks down and spindle shaped structure of microtubules is organised.

Select the correct answer using the codes given below :
CODES :
(a) 3, 6, 2, 1, 5, 4
(b) 3, 6, 1, 2, 5, 4
(c) 3, 2, 6, 5, 1, 4
(d) 3, 2, 6, 1, 5, 4

257. Epistasis should be carefully distinguished from dominance, which refers to non-additivity of alleles at.
   (a) The same locus of a homologus chromosome
   (b) Different loci of a homologous chromosome
   (c) The same locus of non-homologous chromosomes
   (d) Different loci of non-homologous chromosomes.

258. "Mendok" is a gametocide used for inducing male sterility in.
   (a) Onion
   (b) Sunflower
   (c) Maize
   (d) Cotton

259. Composites are developed by using.
   (a) Advanced generation seed mixtures obtained from high yielding intervarietal or interracial crosses.
   (b) Hybrid directly from intervarietal crosses.
   (c) Recurrent selections for specific combining ability.
   (d) The hybrid of an inbred with an open-pollinated variety

260. Plants grown from the seed of an open-pollinated variety of maize.
   (a) Vary in plant height as well as seed characters
   (b) Are uniform in plant height and seed characters
   (c) Vary in plant height but are uniform in seed characters
   (d) Are uniform in plant height but vary in seed characters

261. Superiority of heterozygote leads to
   (a) Fixation of recessive allele
   (b) Fixation of dominant allele
   (c) Maintenance of both the alleles
   (d) Depression of inbreeding

262. Consider the following statements :
   Composites are more popular than the hybrid varieties because the seeds produced by a composite variety
   (1) Can be used again as seed for 3 to 4 years.
   (2) Have negligible inbreeding effect.
   (3) Make varietal maintenance easy.
   Of these statements
   (a) 1, 2 and 3 are correct
   (b) 1 and 2 are correct
   (c) 2 and 3 are correct
   (d) 1 and 3 are correct

263. The initial gene pool of a composite population is composed of
(a) Inbred lines
(b) Isolines
(c) Pure lines
(d) Single plants derived from crosses and/or germplasm lines

264. In cotton, the popularly grown commercial hybrid 'varalaxmi' is the product of
(a) Intraspecific hybridization in *Gossypium hirsutum*
(b) Intraspecific hybridization in *Gossypium barbadense.*
(c) Interspecific hybridization between *Gossypium hirsutum* and *Gossypium barbadense*
(d) Interspecific hybridization between *Gossypium arboreum* and *Gossypium herbaceum.*

265. Jawahar, Vikram, Kisan and Sena, the important varieties of maize are
(a) Double-cross hybrids
(b) Synthetic varieties
(c) Composite varieties
(d) Single-cross hybrids

266. The initial gene pool of a synthetic population is composed of
(a) Plants from an open-pollinated variety
(b) Pure lines
(c) Inbred lines
(d) Isolines

267. In maize, 'Ganga-safed-2' (GS-2) is a
(a) Single-cross hybrid
(b) Double-cross hybrid
(c) Three-way cross hybrid
(d) Double topcross hybrid

268. Assertion (A) : Self-pollination is common in tomato.
Reason (R) : The anthers are split longitudinally in a turnedinward manner so that the pollen falls directly on the stigma.

269. Given that the somatic chromosome number of Triticum aestivum is $2n = 6x = 42$, which one of the following pairs is

correctly matched?

(1) Monosome $2n = 40$
(2) Trisome $2n = 42$
(3) Tetrasome $2n = 44$
(4) Nullisome $2n = 41$

270. When breaks occur in two chromosomes simultaneously in a nucleus and the broken chromosomes rejoin in a new manner, it results in

(a) Deletion
(d) Duplication
(c) Translocation
(d) Inversion

271. Consider the following statements :

(1) Heterochromatin is concentrated near the nuclear envelope and near the nucleolus.
(2) Euchromatin is visible during interphase and is distributed throughout the nucleoplasm.
(3) Euchromatin is concentrated near the nucleolus and near the nuclear envelope.

of these statements

(a) 1, 2 and 3 are correct
(b) 1 and 2 are correct
(c) 2 and 3 are correct
(d) 1 and 3 are correct

272. The segregation of individuals in the F_2 or in a later generation of a cross, which shows a more extreme development of a character than either parent is termed as

(a) Hybridisation
(b) Heterosis
(c) Linkage
(d) Transgressive segregates

273. Heritability may be defined as the

(a) Interaction product of genotype with environment
(b) Sum total of hereditary material present in a species
(c) Degree of resemblance between the original and the selected plants
(d) Proportion of phenotypic variability which is due to heredity.

274. Evaluation of inbreds in maize is carried out in four stages. Open-pollinated variety is involved in the.
(a) Phenotypic evaluation
(b) Top cross evaluation
(c) Single cross evaluation
(d) Double cross evaluation

275. Multiline varieties are mixtures of
(a) Several morphologically different plants having identi cal disease resistance genes.
(b) Bulked progenies of different inbred lines.
(c) Several similar pure lines having different genes for dis ease resistance.
(d) Morphologically identical plants with different genetic make-up

276. Consider the following statements.
The performance of advanced generation synthetic variet- ies, in theory, depends upon the
(1) Number of parental lines.
(2) Source of the parental lines included.
(3) Mean performance of the parental lines.
(4) Mean performance of all possible combinations among all the lines included.
of these statements
(a) 1, 2 and 3 are correct
(b) 1, 3 and 4 are correct
(c) 2, 3 and 4 are correct
(d) 1, 2 and 4 are correct

277. The mechanism of male sterility in self-pollinated crops can be successfully utilised to obtain.
(a) Selfed seed
(b) Mutated seed without radiation treatment
(c) Hybrid seed without emasculation
(d) Sterile seed

278. The basic difference between a synthetic and composite va- riety lines in.
(a) The difference in synthesis
(b) Testing for nicking ability
(c) The mode of pollination
(d) The number of components

279. Which of the following steps are involved in the utilization of hybrid vigour?
(1) Production of uniform homozygous inbred lines.
(2) Crossing inbreds in combination that give uniform and productive single cross (F_1) hybrids.
(3) Crossing single crosses in combination to give productive double cross hybrids.
(4) Mixing single cross F_1 hybrids to give productive double cross hybrids.
Select the correct answer using the codes given below :
CODES :
(a) 1, 2 and 4
(b) 1, 3 and 4
(c) 1, 2 and 3
(d) 2, 3 and 4

280. 'Varalaximi' is a hybrid developed in
(a) Rice
(b) Cotton
(c) Brinjal
(d) Brassica

281. Which of the following are the correct sets of crop, variety and breeding method employed to evolve the given variety?

	Crop	Variety	Breeding method
(1)	Wheat	Shartati Sonara	Mutation breeding
(2)	Sunflower	APSH-11	Heterosis breeding
(3)	Maize	Amber	Population improvement
(4)	Groundnut	TMV-2	Pedigree selection

Select the correct answer using the codes given below
CODES :
(a) 2, 3 and 4
(b) 1, 3 and 4
(c) 1, 2 and 4
(d) 1, 2 and 3

282. Transfer of resistance gene to high yielding self pollinated varieties is achieved by
(a) Hybridization and pedigree selection
(b) Recurrent backcrossing and selection

(c) Hybridization and bulk selection
(d) Hybridization and mass selection

283. Assertion (A) : Doubling the chromosomes of F_1 of an interspecific cross leads to fertility.
Reason (R) : By doubling the chromosomes of F_1 of an interspecific hybrid, each and every chromosome gets its homologue to form bivalents.

284. Assertion (A) : Self-incompatibility is a useful tool for the development of hybrid varieties in several crop species.
Reason (R) : Production and maintenance of inbred lines is tedious and costly in the case of self-incompatible species.

285. Production of a new variety or a hybrid by crossing together two genotypically different individuals is referred to as :
(a) Mass selection
(b) Recombination
(c) Hybridization
(d) None of these

286. Which is the hereditary material in chromosomes :
(a) RNA
(b) ATP
(c) DNA
(d) ADP

287. Genes are present :
(a) Near the chromosomes
(b) On the chromosomes
(c) In the chromosomes
(d) In between the chromosomes

288. Plants having male and female flowers on the same plant are known as :
(a) Monophrodite
(d) Hermaphrodite
(c) Monoecious
(d) Apomixis

289. Chromosome number is reduced to half in :
(a) Meiosis I
(b) Meiosis II

(c) Mitosis
(d) Cytokinesis

290. Self-compatibility is helpful in the development of :
(a) Synthetic variety
(b) Hybrid variety
(c) Pure line variety
(d) Composite variety

291. Appropriate breeding method for transferring disease resistance from wild donor source to an established variety is :
(a) Pure line method
(b) Pedigree method
(c) Back cross method
(d) Bulk method

292. Sepcific combining ability of the parents should be high in order to develop :
(a) Pure line
(b) Synthetics
(c) Composites
(d) Hybrids

293. Name a cereal variety developed by mutation breeding in India :
(a) Sonalika
(b) Jagannath
(c) Kiran
(d) Savita

294. The cornerstone of all plant breeding practices is :
(a) Introduction
(b) Selection
(c) Hybridization
(d) Selfing

295. Dichogamy is regarded as main cause for poor crop in :
(a) Loquat
(b) Strawberry
(c) Custard apple
(d) Plum

296. Mendelian factors segregate in the process of :
(a) Hybridization
(b) Mitosis

(c) Breeding
(d) Meiosis

297. Self-compatibility is helpful in the development of :
(a) Synthetic variety
(b) Hybrid variety
(c) Pure line variety
(d) Composite variety

298. Multilines are produced by mixing equal amounts of seeds of :
(a) Genetically dissimilar lines
(b) Isogenic lines
(c) Inbred lines
(d) Synthetic lines

299. The chromosome number of green gram is :
(a) 12
(b) 24
(c) 36
(d) 48

300. Segregation of gene occurs in :
(a) F_1 generation
(b) F_2 generation
(c) Gametic formation of F_1
(d) F_3 generation

301. Pedigree selection is used in :
(a) Cross-pollinated plants
(b) For crosses at intergeneric level
(c) Self-pollinated crops
(d) Plants difficult to be hybridized

302. Which of the cell-organ functions as suicide bag :
(a) Vacuole
(b) Mitochondria
(c) Lysozome
(d) Golgi complex

303. Chromosome number in bread wheat is :
(a) 22
(b) 32
(c) 42
(d) 62

304. Triticale is a cross between
(a) Wheat and barley
(b) Barley and rye
(c) Wheat and rye
(d) Wheat and oat.

305. An international crop research institute called CIMMYT in Mexico deals with two crops grown widely in India. These crops are.
(a) Rice and jute
(b) Rice and wheat
(c) Maize and wheat
(d) Maize and millet

306. Under normal aerobic conditions, pyruvic acid is oxidised to carbon dioxide and water in cellular organelles known as.
(a) Golgi apparatus
(b) Ribosome
(c) Chloroplast
(d) Mitochondria

307. The high yielding rust resistant wheat variety 'Kalyan Sona' became susceptible to rust some years after its releases and cultivation because of.
(a) Variation in the environment
(b) Mutation in the host plant
(c) Resurgence on the part of the pathogen
(d) Emergence of new races in the pathogen

308. The first maize hybrid developed in India was.
(a) Vikram
(b) Ganga-2
(c) Vijay
(d) Kissan

309. What is the correct sequence of the following for the production of hybrid maize?
(1) Selfing selected open-pollinated populations through several generations to produce homozygous inbred lines
(2) Selecting desirable plants in open-pollinated populations
(3) Crossing chosen lines

Select the correct answer using the codes given below :
(a) 1, 2 and 3
(b) 2, 3 and 1
(c) 2, 1 and 3
(d) 3, 2 and 1

310. Genetics is the study of
(a) Genes
(b) Gene Interaction
(c) Heredity and Variation
(d) DNA

311. At the molecular level point mutations are due to.
(a) Destruction of the bases
(b) Destruction of the double helix
(c) Shifting of a portion of the helix and bases
(d) Alterations of sequences of base in DNA.

312. Specific combining ability of the parents should be high in order to develop.
(a) Hybrids
(b) Composites
(c) Varieties
(d) Synthetics

313. A population at equilibrium developed from intermating a number of inbred lines is called a
(a) Composite variety
(b) Synthetic variety
(c) Hybrid variety
(d) Pureline variety

314. In sorghum somatic chromosome number is 20. What would be its chromosome number in the endosperm?
(a) 10
(b) 20
(c) 30
(d) 40

315. Heterosis is commercially exploited in
(a) Cross-pollinated species
(b) Often cross-pollinated species
(c) Self-pollinated species
(d) Vegetatively propagated species

316. In which one of the following crops maximum exploitation of hybrid vigour during last three decades has been done?
(a) Wheat
(b) Rice
(c) Maize
(d) Cotton

317. A homozygous line developed by self fertilization in a cross pollinated crop is termed as
(a) Pureline
(b) Inbred
(c) Clone
(d) Mutant

318. There are four stages of development of Genetics up to 20th Century. The correct order of their occurrence is
(a) Darwinism, Lamarckism, Mendelism, Weismannism
(b) Lamarckism, Darwinism, Weismannism, Mendelism
(c) Lamarckism, Weismannism, Darwinism, Mendelism
(d) Weismannism, Lamarckism, Darwinism, Mendelism

319. A method of breeding most commonly used when the desired variation is required to be induced in a vegetatively propagated crop is
(a) Polyploidy breeding
(b) Pedigree method of breeding
(c) Mutation breeding
(d) Backcross method of breeding

320. With four bases A, U, G and C the possible number of triplet codons are 64. It there is no uracil, the number of codons will be
(a) 3/64
(b) 9/64
(c) 27/64
(d) None of the above.

321. A mendelian population means
(a) Self pollinated population
(b) Inbred population

(c) Random-mating population
(d) Hybrid population

322. Which one of the following is the site of protein synthesis?
(a) Ribosomes
(b) t-RNA
(c) m-RNA
(d) r-RNA

323. When homologous chromosomes fail to pair in prophase-I of meiosis, the phenomenon is known as
(a) Desynapsis
(b) Non-disjunction
(c) Asynapsis
(d) Disjunction

324. Which one of the following chemicals is used to induce polyploidy?
(a) Ethyl methane sulphonate
(b) Methyl methane sulphonate
(c) Colchicine
(d) Nitrous acid

325. Genes which suppress or enhance the expression of other genes are called
(a) Dominant genes
(b) Recessive genes
(c) Modifier genes
(d) Duplicate genes

326. Which of the following conditions favour natural cross pollination?
(1) Monoecious
(2) Cleistogamy
(3) Protogyny
(4) Protandry
Select the correct answer using the codes given below :
CODES :
(a) 1, 2 and 3
(b) 2, 3 and 4
(c) 1, 3 and 4
(d) 1, 2 and 4

327. A character under study is governed by four allelic pairs. In

such a situation, the number of possible genotypes in F_2 generation will be :

(a) 64
(b) 84
(c) 87
(d) 256

328. Which of the following are relevant to combining ability?

(a) GCA
(b) SCA
(c) IBL
(d) CLO

Select the correct answer using the codes given below :

CODES :

(a) 1, 2, 3 and 4
(b) 1 and 4
(c) 2 and 3
(d) 1, 2 and 3

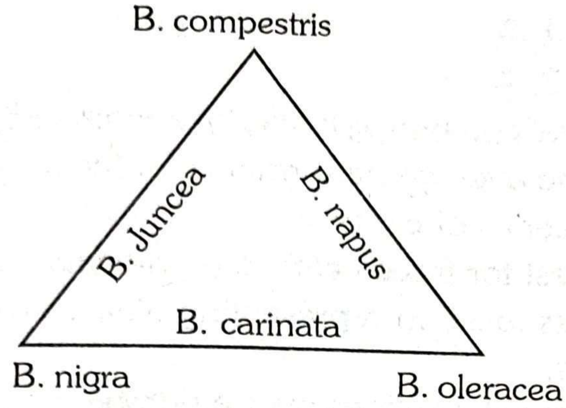
329. Match List-I (Situation) with List-II (Effect) and select the correct answer using the codes given below the lists :

	List-I		List-II
A.	Cytoplasmic male sterility	1.	Induces dwarfism in wheat
B.	Norin-10 gene	2.	Hybrid seed production
C.	Ear to row breeding	3.	Selection procedure in a highly heritable crop
D.	Nullisomic	4.	Plant with one chromosome less than normal

CODES :

	A	B	C	D
(a)	2	1	4	3
(b)	1	2	4	3
(c)	2	1	3	4
(d)	1	2	3	4

330.



On the basis of the above Brassica triangle, the chromosome number of Brassica carinata will be

(a) 4n = 32
(b) 4n = 34
(c) 4n = 36
(d) 4n = 38

331. The phenotypic ratios of progenies in a cross between Aa Bb x aa bb are as follows :

Phenotypes	Ratio
AB	0.31%
Ab	47.0%
aB	48.6%
ab	0.33%

This may be due to the fact that the genes

(a) A and B are in repulsion phase
(b) A and B are in corupling phase
(c) A and B are linked but situated quite far apart on the chromosome
(d) A and B do not belong to the same linkage group

332. Consider the following steps :

(1) Testing the combining ability
(2) Production of inbred lines
(3) Selection of inbred lines
(4) Production of F_1 seed

The correct sequence of these steps in the process of hybrid seed production is

(a) 1, 2, 3, 4
(b) 1, 2, 4, 3

(c) 2, 1, 4, 3
(d) 2, 1, 3, 4

333. The general combining ability of a maize inbred may be defined as the average performance of the inbred
(a) In a series of crosses
(b) At least for three years in a particular location
(c) Across location representing different soil and climatic conditions.
(d) At several locations over a number of years.

334. Which one of the following would give the highest yield in a particular crop?
(a) Single cross hybrid
(b) Double cross hybrid
(c) Composite variety
(d) Composite variety
(d) Synthetic variety

335. Consider the following steps :
(1) Evaluation of parents
(2) Emasculation
(3) Pollination
(4) Bagging and tagging
The correct sequence of these steps in a breeding programme is
(a) 1, 2, 3, 4
(b) 1, 2, 4, 3
(c) 2, 1, 3, 4
(d) 2, 1, 4, 3

336. What would be consequences if the two individuals, female (S_1S_2) is crossed with male (S_3S_4) carrying S alleles (Selfincompatible gene)?
(a) 100% self compatible
(b) 100% self incompatible
(c) 50% self compatible
(d) 50% self incompatible

337. The principal male sterile line introduced for hybrid pearl millet production in India Was
(a) Tift 23 A
(b) BJ-104

(c) MHB-118
(d) CO-2

338. In pigeonpea, the hybrid seed production is made possible due to
(a) Genetic MS lines
(b) CMS lines
(c) CGMS lines
(d) Embryo rescue

339. Which one of the following genes was utilised in the production of high protein composites in maize?
(a) Rht-1
(b) Dee Zee Woo Zen
(c) Opaque - 2
(d) Norin

340. Reselection generation after generation within the intermating of line selects is called.
(a) Pure line selection
(b) Mass selection
(c) Transgressive selection
(d) Recurrent selection

341. Nucellar seedlings are
(a) Inferior to their parents
(b) Weaker and resistant to diseases
(c) Vigorous and true-to-type
(d) Superior to their parents

342. Assertion (A) : Linkage may be a boon to a plant breeder if desirable genes are linked.
Reason (R) : Linkage increases the frequency of parental types and reduces the frequency of recombinant types when compared to that expected with independent segregation.

343. Anthesis is a phenomenon which occurs :
(a) When the flower opens first
(b) After pollination
(c) When anthers are formed in the flower
(d) When fruit drops due to low soil moisture.

344. Opaque-2 maize composites are richer as compared to normal maize in :
(a) Tryptophan
(b) Lysine
(c) Tryptophan and Lysine both
(d) Protein

345. Triticale is :
(a) Interspecific cross
(b) Intraspecific cross
(c) Intergeneric cross
(d) Intrageneric cross

346. Haploids are having :
(a) Somatic chromosome number
(b) Small chromosomes
(c) Very long chromosomes
(d) Gametic chromosome number

347. Bulk population breeding is suitable for :
(a) Fruit crops
(b) Vegetable crops
(c) Small grain crops
(d) Flower crops

348. In sugarcane breeding the initial selection after hybridisation is done in the generation :
(a) F_0
(b) F_1
(c) F_2
(d) F_6

ANSWER

01. c	36. -	71. -	106. -
02. b	37. b	72. c	107. a
03. c	38. d	73. c	108. -
04. c	39. c	74. d	109. a
05. a	40. c	75. b	110. a
06. a	41. b	76. a	111. a
07. d	42. b	77. c	112. b
08. a	43. b	78. a	113. b
09. d	44. a	79. c	114. d
10. -	45. b	80. d	115. -
11. b	46. a	81. d	116. d
12. a	47. c	82. b	117. b
13. c	48. c	83. b	118. d
14. d	49. d	84. b	119. c
15. d	50. a	85. c	120. b
16. d	51. d	86. d	121. b
17. a	52. b	87. -	122. c
18. d	53. a	88. d	123. b
19. a	54. a	89. c	124. b
20. a	55. a	90. b	125. c
21. d	56. d	91. d	126. b
22. d	57. b	92. b	127. -
23. d	58. b	93. a	128. c
24. d	59. b	94. d	129. a
25. d	60. a	95. d	130. b
26. c	61. a	96. d	131. d
27. c	62. d	97. b	132. a
28. a	63. d	98. c	133. d
29. d	64. c	99. c	134. b
30. d	65. c	100. a	135. b
31. c	66. b	101. c	136. b
32. d	67. b	102. a	137. b
33. b	68. a	103. d	138. d
34. a	69. c	104. b	
35. d	70. b	105. a	

139. d	169. c	199. b	229. b
140 . a	170. a	200. a	230. c
141. c	171. c	201. b	231. a
142. c	172. c	202. b	232. a
143. a	173. b	203. a	233. c
144. d	174. a	204. a	234. d
145. c	175. c	205. b	235. a
146. d	176. c	206. c	236. a
147. d	177. b	207. a	237. d
148. b	178. b	208. _	238. c
149. d	179. c	209. d	239. d
150. b	180. b	210. --	240. b
151. c	181. a	211. a	241. d
152. a	182. b	212. c	242. b
153. d	183. b	213. b	243. d
154. d	184. _	214. a	244. d
155. d	185. a	215. x	245. c
156. a	186. d	216. c	246. c
157. c	187. a	217. b	247. b
158. a	188. a	218. b	248. d
159. a	189. d	219. b	249. x
160. d	190. a	220. d	250. d
161. a	191. _	221. d	251. d
162. a	192. c	222. d	(3n,2n,n,2n)
163. b	193. c	223. a	252. b
164. b	194. c	224. c	253. d
165. a	195. a	225. c	254. d
166. a	196. d	226. d	255. d
167. c	197. b	227. d	256. b
168. c	198. d	228. c	257. b

258. x	287. b	316. c	344. b
259. a	288. c	317. b	345. c
260. a	289. a	318. c	346. d
261. c	290. b	319. c	347. c
262. a	291. c	320. c	348. c
263. d	292. d	321. c	
264. c	293. b	322. d	
265. c	294. b	(Specific Site)	
266. d	295. c	323. c	
267. d	296. d	324. c	
268. a	297. b	325. c	
269. c	298. a	326. c	
270. c	299. b	327. d	
271. c	300. c	328. x	
272. d	301. c	329. c	
273. d.	302. c	330. d	
274. b	303. c	331. a	
275. c	304. c	332. d	
276. x	305. c	333. a	
277. c	306. d	334.	
278. b	307. d	335. b	
279. c	308. b	336. a	
280. b	309. c	337. a	
281. c	310. c	338. a	
282. b	311. d	339. c	
283. a	312. a	340. d	
284. b	313. b	341. c	
285. c	314. c	342. a	
286. c	315. a	343. a	

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